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Scientific Control of Fertilizer Applications

An account of investigations pertaining to potash applications to the fields of the Ewa Plantation Company is given in this issue by W. P. Alexander. Through work extending over six years, embracing 45 field experiments, 1,000 soil analyses, 1,500 juice analyses, that plantation divides its cane area into six zones in relation to potash applications.

As a result of the work to date, 4,500 acres receive no potash because it is found profitable to leave it off; 800 acres receive extra large applications because yields on these lands respond to such treatment. The remainder of the plantation receives moderate applications because the data in hand indicate that moderate applications are appropriate.

This work at Ewa is a fine example of a thoroughly comprehensive application of science to a plantation problem, not a major problem compared to nitrogen fertilization or irrigation studies, but a secondary problem of sufficient financial importance to merit the attention it has received.

The day of uniform fertilization to all fields of a plantation is gradually passing, as precise information accumulates pointing to the more economical procedure of zoning the area on the basis of actual plant food requirements.

Adventitious Buds or "Node Galls" in Sugar Cane

Three articles on the subject appear in this number: a descriptive article by H. L. Lyon with illustrations of some extreme forms, an article by Kamerling, originally published in Java in 1900, and a progress note by C. C. Barnum, reporting negative results in the attempts to date to infect other canes by injecting the juice of the proliferated tissue.

The type of malgrowth that has appeared on a number of the Uba seedlings and other varieties is interesting but not new. Observations as early as 1914 record instances of it in Hawaii on the stalk, and cases of "bunch top," which is said by Dr. Lyon to be but another manifestation of the same nature, date back to 1910.

We are dealing with one of two things, a condition inherent in the cane itself, resulting in the false growth, occasionally, in many varieties, and rather consistently in certain of the seedlings; or possibly an old and well distributed disease of an infectious nature, to which the great majority of our varieties are highly resistant and to which some of the seedlings are susceptible.

Of the varieties, other than Uba progeny, Makaweli No. 1 shows this excrescent tissue the most, but without the deforming effect upon stalk development noted in some of the Uba hybrids, and quarter-breeds. Of the latter groups the worst of them had better be eliminated for they have small chance to become commercial canes and they are undesirable for breeding purposes. There seems to be no reason to curtail the extension of fairly promising seedlings showing the gall-like excrescences in mild form, for our standard varieties also manifest this trouble in slight degree.

Rat-Damaged Cane

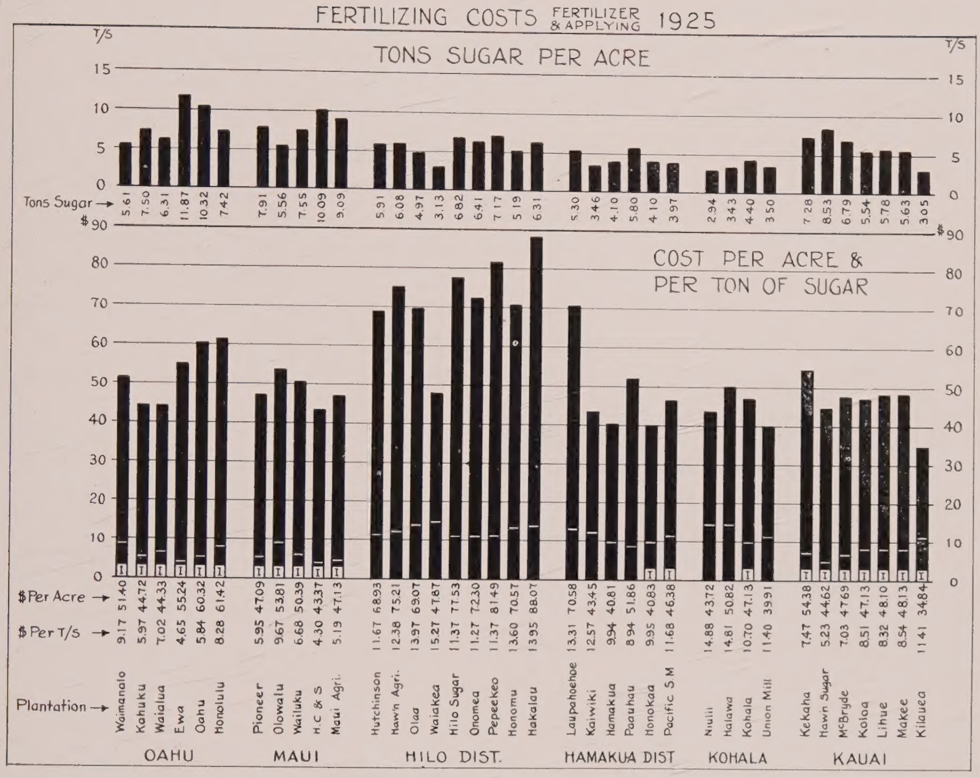
The Honokaa Sugar Company and Pacific Sugar Mill report that after a number of years of intensive poisoning they have succeeded in reducing the rat population of their fields far below their most sanguine expectations. The rat-damaged cane this year amounted to less than one-half of 1 per cent as compared with some 60 to 70 per cent five years ago.

Fertilizer Costs

The accompanying diagram showing fertilizer costs was prepared, originally, at the Hawaiian Agricultural Company, James Campsie, manager. As shown here, the diagram differs from theirs only in that the plantations have been grouped with respect to their geographical location. This comparison of fertilizer costs, per acre, and per ton of sugar, shows in general higher costs per ton for unirrigated lands than for irrigated ones. This difference is due in part, at least, to the better quality of cane in the dry districts. A comparison of fertilizer costs per ton of cane would not show so much variation. Fertilization must be planned with due consideration of probable yield of cane rather than sugar. Three pounds of nitrogen per ton of cane, with nitrogen at 20 cents per pound, amounts to 60 cents per ton of cane. At 7 tons of cane per ton of sugar, we have the cost of nitrogen, unapplied, \$4.20 per ton of sugar. At 10 tons of cane per ton of sugar the nitrogen cost would be \$6. At 4 pounds of nitrogen per ton of cane the foregoing values become \$5.60 and \$8 in place of \$4.20 and \$6.

Phosphoric acid applied at the rate of 60 pounds per acre, at 7 cents per pound, costs \$4.20 per acre, to be divided according to yield:

30 tons per acre—14 cents per ton of cane
60 tons per acre— 7 cents per ton of cane
90 tons per acre— 4⅔ cents per ton of cane



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Potash applied at 60 pounds per acre, at 5 cents per pound, costs $3 per acre, to be divided according to yield:

30 tons per acre—10	cents per ton of cane
60 tons per acre— 5	cents per ton of cane
90 tons per acre— 3⅓	cents per ton of cane

Potash is often applied at 100, 150, 200 pounds per acre, and when this is the case the foregoing values are multiplied accordingly.

It would seem, therefore, that the cost of phosphoric acid should average 7 cents per ton of cane and seldom exceed 14 cents; that the cost of potash should average 5 to 10 cents per ton of cane and seldom exceed 30 cents; that the cost of nitrogen per ton of cane should average 60 or 70 cents and seldom exceed 80 cents. Combining these ingredients it is thus seen how there may be a range in fertilizer costs between 72 cents and $1.24 per ton of cane, or, in the event of the omission of phosphoric acid and potash, the minimum might be around 60 cents per ton of cane. Since the tons of cane required to make a ton of sugar on the different plantations vary between the limits of 7 to 11, one can understand a variation in cost of fertilizer per ton of sugar between the extreme limits of $4.20 ($7 \times 60$ cents) and $13.64 ($11 \times \$1.24$). Without an analysis of this kind the range of cost of fertilizer per ton of cane as given in the diagram would be somewhat puzzling.

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* Hilo district should read Kau, Puna, and Hilo districts.

Available Surface Water*

By Max H. Carson

This subject has been covered in the report of the Honolulu Water Commission made to the Mayor and Supervisors of the city of Honolulu in 1917, much more thoroughly and in considerably more detail than it would be possible for me to cover it in the time allotted to this subject. They made extensive investigations covering a considerable period of time and had at their disposal the services of J. T. Taylor and his engineering staff.

Lorrin A. Thurston, who was chairman of that Commission, has summarized their findings on pages 14 to 29 of their published report, so admirably that there is little more that can be said without the "complete and detailed investigation, survey and report" by an expert hydraulic engineer which they recommend. In general the available surface water is in four classes: (1) Normal flow in the valleys immediately back of Honolulu from Palolo at the one end to Kalihi at the other; (2) Flood water from these valleys and possibly from Moanalua which might be stored in reservoirs; (3) Water which might be collected in ditches along the windward coast from opposite Kalihi north to Waiahole, and brought through to Kalihi in tunnels; and (4) Water which might be collected from Kaneohe south and brought through tunnels to Manoa. Then, of course, there is what we might call a fifth class in the possibility of using water from Waiahole Tunnel.

Taking these various sources up by classes, there is the normal flow from the valleys immediately back of Honolulu for first consideration.

Normal flow is a rather difficult term to define. It certainly cannot mean average flow, for that is made up partly of flood waters. Neither can it mean minimum, although for consideration as a supply for domestic consumption, if no other source were available, it would necessarily approach the minimum. Let us say then that normal flow is an amount which can be depended on for 80 per cent of the time, i. e. that the stream will not flow less than the specified amount more than 70 days a year, or roughly two and a half months.

Then normal flow would probably amount to about 6 or 7 million gallons a day exclusive of Nuuanu which is already pretty well utilized. Most of this water is used for irrigation or is subject to such use so that its use for city supply would require the acquisition of a good many water rights.

The flood waters from these valleys, however, are available provided they can be successfully stored. The average flow of these streams, again excluding Nuuanu, totals probably about 15 million gallons per day. If we assume that 6 million of this is normal flow, it leaves a remainder of 9 million gallons a day available for storage.

* Presented at first annual meeting of Hawaiian Academy of Science, Honolulu, May 19-22, 1926.

This, however, comes in short, sharp floods of very high rates of flow and would require rather large collection works to take care of it all. The streams in Manoa Valley have run at a combined rate as high as 590 million gallons a day for short periods of time. If we assume that we would lose half of these peaks, through inability to catch them, that leaves us 4½ million gallons available for storage. This taken together with the normal flow gives us 10 or 11 million gallons a day additional water available from the streams back of Honolulu.

Mr. Jorgensen estimated for the Honolulu Water Commission that 7½ million gallons a day could be collected in ditches along the windward coast north of Kalihi and brought through the mountains at about 800 feet elevation. So far as I know no more recent records exist that throw any further light on this plan, but I believe Mr. Jorgensen's estimate is a reasonable one.

Any water collected south of Kalihi and brought through into Manoa Valley would have to be collected at lower elevations, but possibly another two or three million gallons a day could be obtained in this manner, at 400 or 500 feet.

These latter projects are, however, limited by the demand that is arising for this water on the Koolau side of the island. Already plans are being made to use more than a million gallons a day of the water Mr. Jorgensen's plan would have diverted to the Kalihi tunnel, for the supply of the Insane Asylum and the communities growing up along the Kailua beaches; and other springs are to be used for the supply of Waimanalo and possibly Lanikai.

Suppose we say then, that we shall have left 4 million gallons a day from that source which might be diverted to Honolulu; we would have available from all these sources combined about 15 million gallons a day that could be counted on.

In this discussion I have, so far, purposely left out of consideration the possibility of developing further supplies in the tunnels that would be necessary to conserve the water I have been talking of. Tunnels, particularly through to Kalihi and Manoa would doubtless develop considerable quantities of ground water as was pointed out in the report of H. S. Palmer to the Board of Supervisors in 1921.

This outline has necessarily been sketchy. To go into more detail, or to express quantities of flow in more exact figures would call for a mass of supporting data and a correlation of plans for conservation that cannot be taken up in the scope of this paper. For instance take the flood mentioned in Manoa Valley when the combined flow of the various branches of the stream was at the rate of 590 million gallons a day for a short period. If the collection works were designed, as suggested in the Honolulu Water Commission report, to catch 50 million gallons a day to be carried to Nuuanu we could get only about 8 per cent of the peak. Twice as large a tunnel would catch 16 per cent of the peak and probably 50 per cent of the entire flood. But this would do little good unless there is reservoir capacity to hold it, and the reservoirs in Nuuanu would be receiving flood water from Nuuanu, and possibly from Kalihi at the same time.

These things require a detailed study, not only of the average amounts of flow, but of the character of the flow, which I believe the Honolulu Sewer and Water Commission is making, and which require continuous records of stage such as are

obtained by water stage recorders. The U. S. Geological Survey, cooperating with the Division of Hydrography of the Territory, has maintained such stations in Manoa, Nuuanu and Kalihi Valleys since about 1911. Stations are now being established in cooperation with the Honolulu Sewer and Water Commission in Palolo and Moanalua to study the character of floods.

In concluding let me point out that all these sources taken together and added to what may be expected from tunnelling will little more than equal what the city is now pumping from the artesian supply, unless we go to Waiahole and thus cripple the plantation it supplies. Hence, if the city grows as we expect it to, we cannot hope to escape the necessity for conservation of what we already have.

The Honolulu Type of Artesian Structure*

By Harold S. Palmer

Geologists define ground water as that water in voids in the rocks which obeys hydrostatic laws. If it exists in sufficient abundance it is recoverable by wells or may discharge naturally as springs, if other conditions are favorable.

In the present connection we may consider two types of ground water: first, ordinary ground water or phreatic water which is not under appreciable hydrostatic pressure; and, second, artesian water which is under enough hydrostatic pressure so that if a hole is sunk into the water-bearing rock (aquifer), the water will rise in the hole to a level above that at which it enters the hole. For use in other connections we could recognize other types of ground water.

It is certain that virtually all of the economically valuable ground water is derived from rain, from melted snow, or from some other form of precipitation of atmospheric water. Two lines of argument lead to this conclusion. It is a valid generalization that regions of abundant precipitation have abundant ground water, and that regions of scanty precipitation have scanty ground water, except where there is a demonstrable underground connection from the dry region to a nearby moist region. It is also a truism that in any given region ground water is most abundant during and after times of abundant precipitation and that ground water is scarce after droughts. The universal coincidence of the abundance of precipitation with the abundance of ground water, both in time and in space, clearly show that ground water for the most part has its origin in precipitation.

The second line of reasoning in proof of this conclusion relates to the composition of ground waters. Juvenile waters, or waters appearing at the surface of the earth for the first time, such as the waters discharged at and around volcanoes, are strongly mineralized. In some parts of the world, such as central

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* Presented at first annual meeting of the Hawaiian Academy of Science, Honolulu, May 19-22, 1926.

Australia, waters travel a very long distance underground and reach great depths. Such waters, by reason of the high temperature and high pressure are particularly able to dissolve a little of the rocks through which they pass and are consequently impregnated with much mineral matter. This high mineralization is also favored by the fact that such waters are in contact with rock for a long time, as their subterranean journey is long. Such mineralized waters, however, are relatively scarce. Most ground waters are low in dissolved mineral matter, which implies that they are derived, and not remotely derived, from some very pure water. The only conceivable source of such pure water is from rain or other form of precipitation from the atmosphere.

Before considering the somewhat unusual artesian conditions at Honolulu it will be well to consider the more usual causes of artesian pressure, and to consider how ordinary ground water occurs in most oceanic islands.

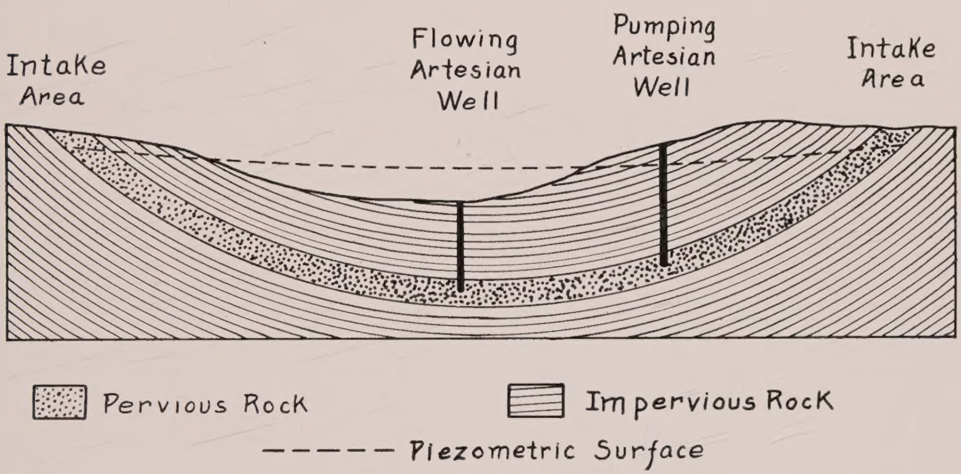

Fig. 1.

The term "artesian basin" is properly reserved for conditions similar to those illustrated in Fig. 1, where there is an extensive bed of rock of such texture that water can readily flow along it. The perviousness of such a rock may be due to an infinite number of tiny chinks between sand grains, to cracks produced by mechanical stresses or to various other causes. The pervious bed has been warped in such a way that edges outcrop at high elevations on all sides of an area in which the bed has been warped down to a considerable depth. The pervious bed is able to absorb water that reaches the high areas of outcrops. This water may be rain or melted snow or ice that has fallen on the "intake area" and soaked in, or it may be water from other regions carried by streams to the intake area.

The pervious bed is overlain and underlain by impervious beds. In many places the impervious rock is one of so fine texture that water is prevented from passing through its voids by molecular adhesion of the water to the walls of the voids. The impervious beds restrain the escape of water from the pervious beds, and thus cause more or less "head" or hydrostatic pressure to develop. The con-

dition is analagous to an imaginary water works (see Fig. 2) in which there are two reservoirs connected by a main pipe. The two reservoirs of Fig. 2 are analagous to the two intake areas of Fig. 1; the hole through the main pipe is analagous to the pervious bed; and the walls of the pipe are analagous to the impervious beds. If the water-bearing bed were perfectly pervious and if the impervious beds were perfectly impervious, water would rise through wells drilled into it and would rise to the same elevation as the intake areas. This would be analagous to the rise of water in various service pipes tapped into the main of the hypothetical water works system. In nature, however, the pervious bed presents considerable frictional resistance to the movement of water through it and the impervious bed is not perfectly impervious and dissipates some of the head by

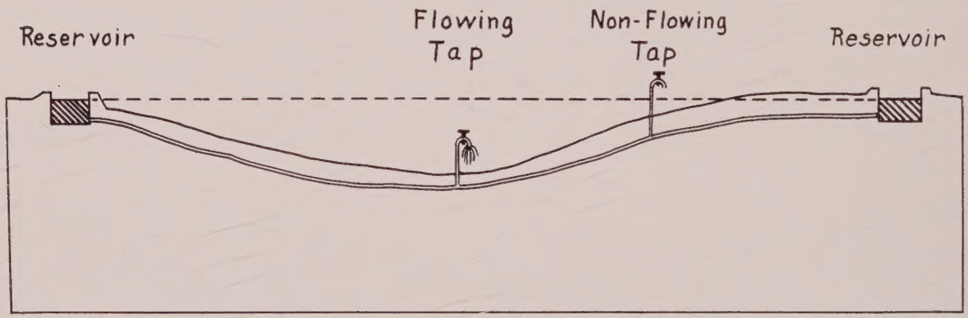

Fig. 2.

letting water escape. Therefore, water will not rise in wells to the same height as the intake areas. It rises to the height of a surface known as the "piezometric surface" (Greek, piezo meaning pressure, and metron meaning measure). Whether an artesian well will flow or will have to be pumped depends on whether the piezometric surface is higher or lower than the ground surface at the point where the well is sunk. Wells illustrating the two conditions are shown in Figs. 1, 3 and 8. The non-flowing or pumping wells are analagous to faucets in the upper stories of high buildings, or on high ground which fail to function at times because of their high elevation.

A more common condition of rock structure than the "artesian basin" is the "artesian slope" in which the pervious bed is inclined in only one direction. This is analagous to the usual sort of water works where the distributing mains lead from a single reservoir. If the main of such a system were open at the distal end the water would escape and little or no water would be discharged at the various service connections. Similarly the distal end of the pervious bed of an artesian slope must be closed in order to prevent escape. Fig. 3 illustrates two ways in which this sealing may be accomplished. In the upper diagram the pervious bed thins toward its distal end with the result that the overlying and the underlying impervious rocks come in contact. In other artesian slopes the texture of the pervious bed changes and becomes impervious, as indicated in the lower diagram. Wells will be failures if drilled at places more remote from the intake area than the point of thinning out or the point of change to impervious, as shown at the extreme right in these diagrams.

The artesian basin, from the geometric point of view, may be considered as two artesian slopes whose pressures oppose one another and prevent the escape of water.

Before considering the causes of artesian pressure at Honolulu it will be well to see how water would be distributed in homogeneously pervious oceanic islands. Fig. 4 is a vertical cross section of an island which consists of rocks of uniform and high perviousness. It is further supposed that this island has no rainfall or other form of precipitation. It is clear that in the course of time sea water will work its way in from the shores and all the voids that lie below sea level will be

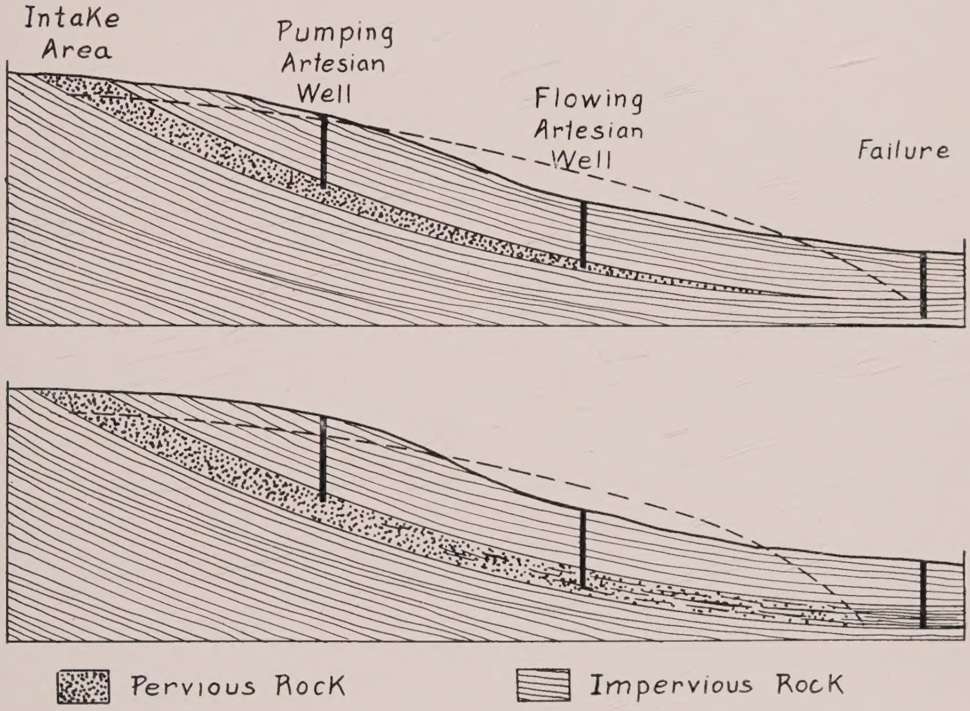

Fig. 3.

filled with sea water. The voids above sea level will contain air, except for a thin zone just above sea level into which some sea water will be raised by capillary action.

Let us modify the preceding conditions in one particular. Let us suppose that there is a fair amount of rainfall on the island. Some of the rain will be evaporated shortly after falling, some will flow off in surface streams, and some will soak into the ground, since the rocks of which the island is composed are pervious. The water that soaks into the ground will move vertically downward in obedience to gravity until it meets some obstacle. In the case of our homogeneously pervious island the first obstacle will be the zone in which the voids are filled with sea water. The fresh water will react in two ways. It cannot displace the salt water completely, because the salt water is heavier and tends to be held in place

by pressure transmitted from the open water along the shores. Therefore, the fresh water will in part move shoreward over the surface of the salt water. This movement will be resisted by interstitial friction and the fresh water will therefore be backed up more or less. Being backed up will cause it to rest on the salt water with more or less weight, thus producing a pressure that will partly counteract the pressure applied to the salt water from the shores. Thus the fresh water will press the salt water downward and to some extent outward. The amount by which the salt water will be depressed depends on how much pressure the overlying fresh water exerts, and this in turn depends on the distance from the shore. The greater the distance from the shore, the greater will be the interstitial friction against which the fresh water must move. The greater the frictional resist-

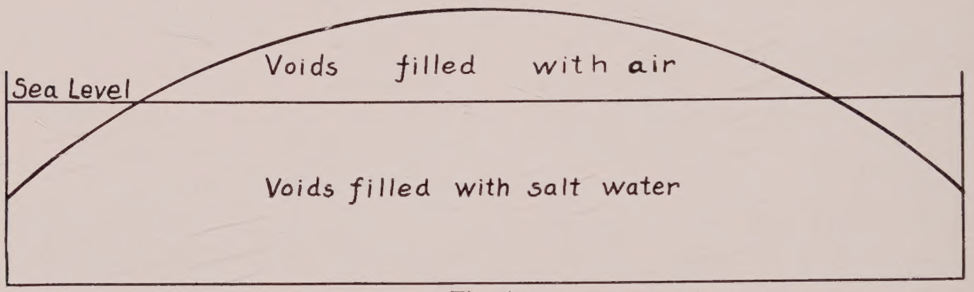

Fig. 4.

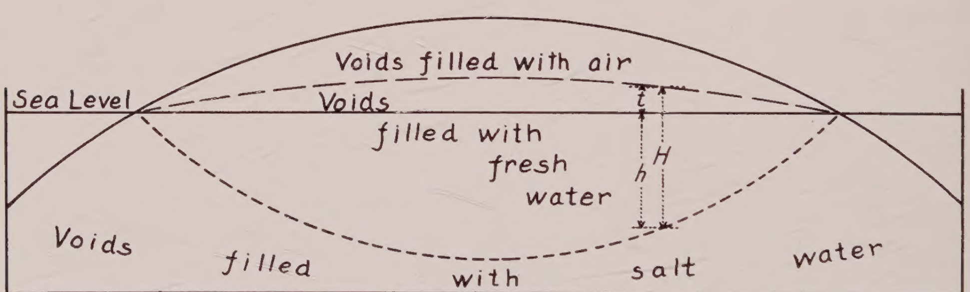

Fig. 5.

ance, the higher the fresh water will be backed up and the greater the pressure it will apply to the salt water. The greater this pressure, the greater the depression of the contact of the fresh with the salt water. Thus there will be under our homogeneously pervious, rainy island the following zones (see Fig. 5):

1. A zone in which the voids are filled with air. (Note: This zone may contain some water that is in transit from the surface downward, having been absorbed only recently.)

2. A zone, shaped like a bi-convex lens, in which the voids are filled with fresh water. The curvature of the lower side of this lens will be much greater than the curvature of the upper side.

3. A zone, extending downward as far as voids exist, in which the voids are filled with sea water.

Since the second zone contains fresh water it is of importance in problems of ground water supply. The thickness of the fresh water lens depends in part on the perviousness of the rock, and is greater in the less pervious rocks. The

thickness also depends on the rate of supply of fresh water and is greater with a large supply of fresh water. At any point the thickness of the part above sea level (t in Fig. 5) is to the total thickness (H in Fig. 5) as the difference in specific gravity of the fresh and the salt water is to the specific gravity of the salt water. If we let g be the specific gravity of the salt water unity, the specific gravity of the fresh water, and h the depth of the fresh-salt transition below sea level, we may write the following equations:

$$H = h + t \qquad (1)$$

or $$H = hg \qquad (2)$$

whence

$$h = \frac{t}{g - 1} \qquad (3)$$

The sea water around the Hawaiian Islands has a specific gravity of about 1.025, and therefore $g - 1 = 1.025 - 1.000 = 0.025 = 1/40$. Therefore in the Hawaiian Islands the fresh water zone extends about 40 times as far below sea level as it extends above sea level.

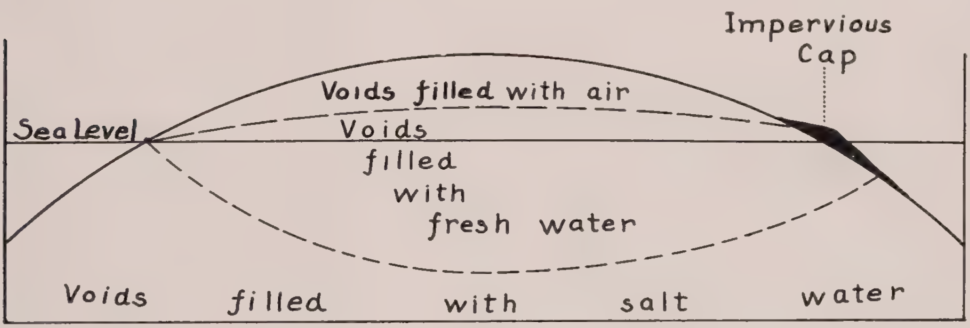

Fig. 6.

The protuberance of the fresh water zone above sea level is due to the fact that the fresh water is lighter than the sea water and floats upon it. Brown* gives a summary of laboratory experiments and of field observations on the coasts of the Netherlands and Germany which shows the validity of this theory, which is named the "theory of Herzberg" after the German geologist who first gave it wide publicity.

In attacking this problem we first considered an island composed of uniformly pervious rocks with no rainfall. We then modified this by supposing the island to have rain. Let us modify the island still further by supposing that there is a capping of impervious rock extending somewhat above and below sea level on the right-hand side, as indicated in Fig. 6. Such a cap would oppose the movement of fresh water seaward, with the result that the fresh water body would have an unusually great thickness beneath the cap and landward from it. It would also prevent escape of fresh water to the sea in a zone extending both above and below sea level. If the cap extended only a little way above sea level but far

* Brown, John S., A Study of Coastal Ground Water, with especial reference to Connecticut: U. S. Geol. Survey, Water-supply Paper 537, pp. 14-20, 1925.

below sea level, the fresh water might be backed up enough so that it would overflow and form springs at the upper edge of the cap. It is probable that the springs along the shores of Pearl Harbor are due to this effect. If the cap extended only a little way below sea level it would produce only a little raising of the fresh water. We may summarize the effect of such a cap by saying that it may hold fresh water up to an elevation above sea level equal to one-fortieth of the depth of the lower edge of the cap below sea level, provided the cap extends this much above sea level.

Let us next consider the conditions at Honolulu. The Koolau Range, back of Honolulu, was built by the pouring out on top of one another of a great number of lava flows. In my opinion, the flows originated from a series of vents along a line that extended northwestward from about Puu Olomana. At all events it is certain that the vents lay to windward of the present Koolau divide, and the lavas flowed to leeward. We are not now concerned with what happened on the windward side, which is a more complex story. The flows tended to fill up any depression that may have been formed in older flows, with the result that a rather smooth cone, similar to the leeward slopes of Haleakala, was formed. In time, volcanic activity ceased, and streams slowly carved radial valleys in the conical slope. Wilhelmina Rise is a piece of the conical surface which has not been appreciably altered by stream cutting. The debris removed by the streams accumulated along the shores, a process that for some obscure reason has not been as effectively followed out elsewhere in Hawaii. The mud of the Waikiki flats originated in this way. Additional matter was laid down along with these stream-borne sediments, and included reef-rock made by corals and other lime-secreting animals and also included some volcanic ejecta from Diamond Head, Round Top, Tantalus, and other small craters. The result of all these is a roughly triangular prism of relatively impervious rock, largely mud, clay and coral, which has rather a flat surface. The flat surface includes the part of Honolulu below an elevation of about forty feet, and forms a coastal plain a mile to a mile and a half wide (see Fig. 7).

The lavas beneath the impervious cap are very pervious. The voids in the lava include the following types:

1. Intercrystal Spaces. When cooling and crystallizing the various mineral grains of which the rock is composed may develop minute voids between them. These are too small to be of importance in ground water supply.

2. Shrinkage Cracks. In cooling a lava flow must shrink. This causes tensional stresses in the rock, which result in cracking. These cracks are in general roughly vertical, that is, they are parallel to the shortest dimension of the flow, the thickness. These cracks may be minute or of fair size. The larger ones are effective water carriers because they extend a fairly long distance.

3. Gas Pores. Live lava consists of a complex solution of liquid rock and gases. These gases, on being set free, make bubbles. In extreme cases the lava may resemble a frozen froth or foam. The lavas at Honolulu vary greatly in the abundance of gas vesicles. Where the vesicles are of fairly good size, are abundant, and connect with one another they may transmit a great deal of water.

4. Clinker Voids. When an "aa" lava flow is in motion the chilled and brittle crust is dragged along by the viscous lava beneath. The crust is broken by this drag into extremely rough and irregular pieces. Since these pieces or "clinkers" do not fit together, there are large voids between them. These are very effective in carrying ground water.

5. Bedding Voids. When a later flow is poured out over the irregular surface of an earlier flow, it is impossible for the two to come into perfect contact. The younger flow would have to be very fluid to fit itself to the irregularities of the older flow. But a flow advances over a sort of pavement that it has laid down for itself consisting of its own chilled, solidified and shattered crust. Such voids may be made between the successive batches of lava that are discharged in a

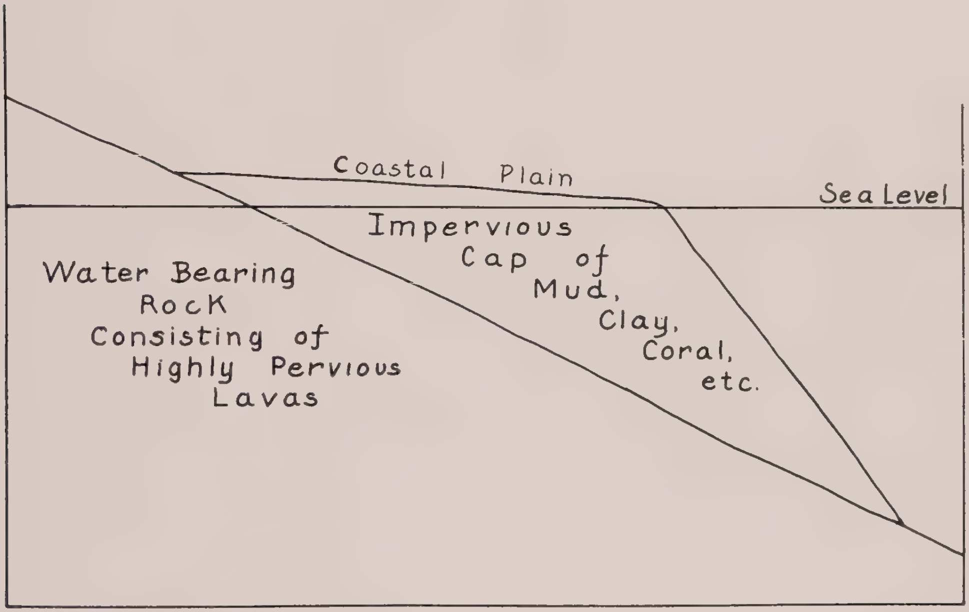

Fig. 7.

single short spasm of activity as well as between flows made a long time apart. Bedding voids are probably the most effective carriers of ground water in the Hawaiian lavas, for they are not only very abundant, but are also very open so that they present little frictional resistance to the movement of water. Moreover, bedding voids may form pervious zones that extend great distances.

6. Subsequent Cracks. Should the lavas, after coming into place and solidifying, be subjected to mechanical stress they may be cracked. Such stress might be due to jarring by earthquake waves, to faulting, or to settling. Subsequent cracks are fairly extensive and may or may not be open enough to carry water.

7. Lava Tubes. Many lava flows develop a hard crust by the cooling and solidification of the upper surface. Later the supply of lava for the particular flow may cease and the liquid lava stream may drain out leaving a long tubular opening under the crust. Lava tubes formed in this way would be as good as artificial pipes for carrying water.

8. Tree Molds. Where a lava flow invades a forest it may kill but not burn up some of the trees. The lava sets around the charred tree, and forms a tube when the tree finally rots away. These are not of importance in the matter of ground water supply.

From the preceding inventory of the openings in lava rocks it is clear that these rocks are highly pervious and constitute a splendid water-bearing rock mass. As indicated above, in the neighborhood of Honolulu, a capping of relatively impervious mud, clay, coral, etc., overlies the highly pervious lava rocks. The thickness of cap rock through which it is necessary to drill in order to reach the pervious rocks varies from place to place. In general it is greater near the shore and less inland because of the general slope of the pervious rocks. Other irregularities are due to the fact that the streams that eroded the original volcanic slope cut valleys at a time when Oahu stood at a higher level than it does now. These valleys have been more or less filled with material like that of the coastal plain. If a well is started at a point overlying such a buried valley, it will obviously be necessary to drill farther to reach the lava rock than would be the case with a well placed otherwise. An example of this was found in the recent drilling of new wells at the Kalihi pumping station.

The abundance and distribution of ground water depend on three factors over which man has virtually no control: the structure of the rocks, the force of gravity, and precipitation. Precipitation provides the water, gravity drives it, and rock structure determines in what direction it will move and where it may be stored.

Rain falling in the region back of Honolulu in part sinks into the ground, and moves vertically downward until it is close to sea level. Then it tends to move seaward, part of it toward Honolulu and part of it toward Kailua (see Fig. 8). The part that moves toward Honolulu meets with the obstacle formed by the

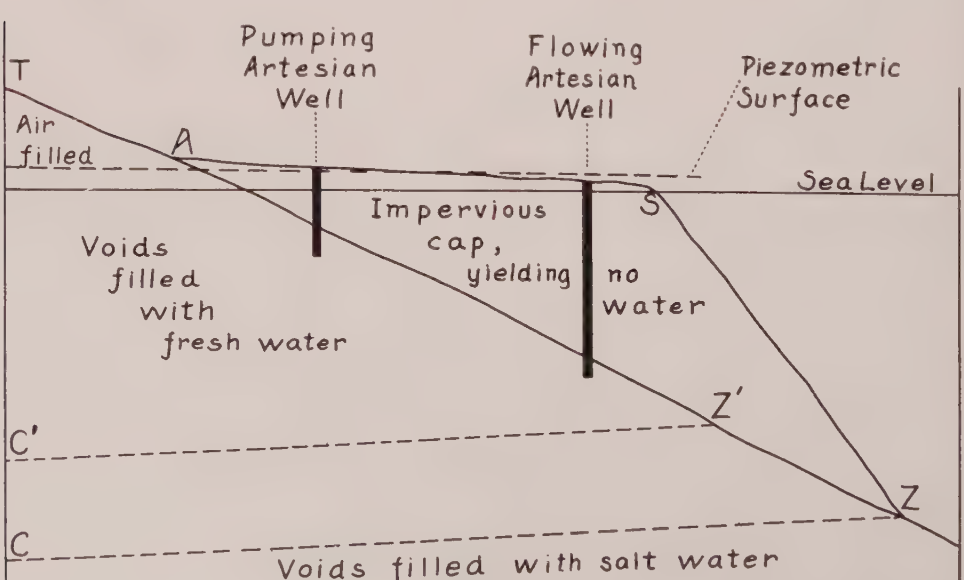

Fig. 8.

impervious cap, and, according to the principle of Herzberg, is backed up. A well drilled down through the impervious cap and into the highly pervious lava rock beneath will enter a zone in which the voids are filled with water. Since the cap extends up to a moderate elevation and since there is in general an ample supply of rain in the intake region the thickness of the body of fresh water held back by the Herzberg principle is great. It was originally about 1,700 feet thick. At the bottom of the well the water will be under the pressure appropriate to the amount it is lower than the upper surface of the zone in which the voids are filled with water. (This pressure is usually expressed as a "head," that is, as the number of feet depth of water necessary to produce the pressure in question. "Head" may be converted to pressure in terms of "pounds per square inch" by multiplying the number of feet of head by 0.434.) As a consequence of the pressure the water will enter the well at the bottom and rise to such an elevation that its weight will produce a downward pressure that will just balance the upward pressure at the bottom of the well. This elevation will, of course, be the same as the elevation of the upper surface of the region in which the voids are filled with fresh water, less a small amount due to reduction of pressure by friction as the water flows seaward through the rock openings.

It happens that the seaward part of the cap at Honolulu is only a little above sea level though the inner edge is rather higher. The seaward edge of the coastal plain is lower in elevation than is the upper surface of the zone in which the voids are filled with water. A well drilled in the seaward region through the impervious cap will enter lava rock in which the voids contain water under a pressure appropriate to a depth greater than that of the well. Consequently such a well will be a flowing artesian well, the rate of flow depending on various factors, one of the most important of which is the difference in elevation between the mouth of the well and the piezometric surface or upper surface of the zone in which the voids are filled with fresh water.

When the first artesian wells were drilled in Honolulu, in 1880, the water rose about 42 feet above sea level. This would imply that the fresh water zone extended about 1,700 feet below sea level. ($42 \times 40 = 1680$.) This 1,700 feet depth is diagrammatically shown as the line C-Z in Fig. 8. Due to the diffusion of salt and fresh water into each other, the contact is a zone of considerable thickness. The artesian head is due to a number of causes, one of which is the more or less complete prevention of seaward escape of water. Various ways in which escape may be retarded have been described, but it may be well to emphasize at this point the concept that at Honolulu the action tending to prevent seaward escape is the back pressure due to the denser sea water. The effectiveness of this back pressure has been partly counteracted by the artificial opening of many channels of escape through the impervious cap. These artificial openings are the many artesian wells. The action is somewhat similar to that which we experience in houses which are served by a single connection to the public water main but which have a number of faucets. The more faucets there are in use, the less the pressure at any one faucet. The analagous proposition is: The more artesian wells there are in use, the less the pressure at any one artesian well.

The head of the artesian water has steadily decreased. The best records are those that have been kept at the Oahu College (Punahou School) well which are graphically shown in Figs. 9 and 10. Fig. 9 shows the variation of the monthly average head for the eight years from 1910 to 1917, inclusive. During this period the head fluctuated so that at its greatest it could raise water in the well to an elevation of 32.5 feet above sea level. In 1914 and 1915, it dropped to 27.8 above sea level. Early in 1916, it rose again to about 32.4 feet as a result of excessively heavy rains in November and December, 1915, and January, 1916. These three months totalled 38.22 inches of rain at the Honolulu Weather Bureau, which is 3.2 times the mean (11.96 inches) for these months. It will be noticed that in each of the eight years shown in Fig. 9 there was a maximum head sometime during the first four months, that is after the water of the rainy season had had time to percolate through the rocks and reach the artesian system. Similarly the minimum in each of the eight years occurred between August and November, that is after the dry season when there was little recharge and a large draft for

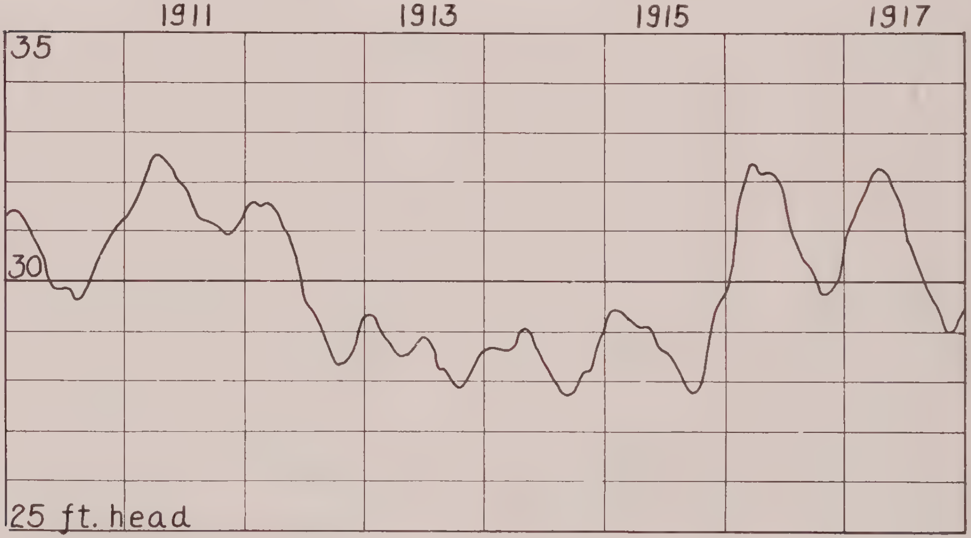

Fig. 9.

irrigation. The artesian head depends not only on the back pressure of the sea water but also on the rate of supply of water from the intake area. This is only one of many examples that show how the local rainfall is reflected in the artesian head.

Three lines are shown in Fig. 10, which relates to the head at the Punahou well from 1888 to 1925, inclusive. The upper line shows the highest monthly average head recorded each year, and the lower line shows the lowest monthly average head. Data are lacking for the four years from 1905 to 1908, inclusive, and the dotted portions indicate heads computed from rain measurements.* The smooth curve is a generalized average and shows the effect of a continued draft

* G. K. Larrison, Arthur G. Smith, and T. F. Sedgwick, Report of the Water Commission of the Territory of Hawaii, Appendix, Fig. 2, Honolulu, 1917.

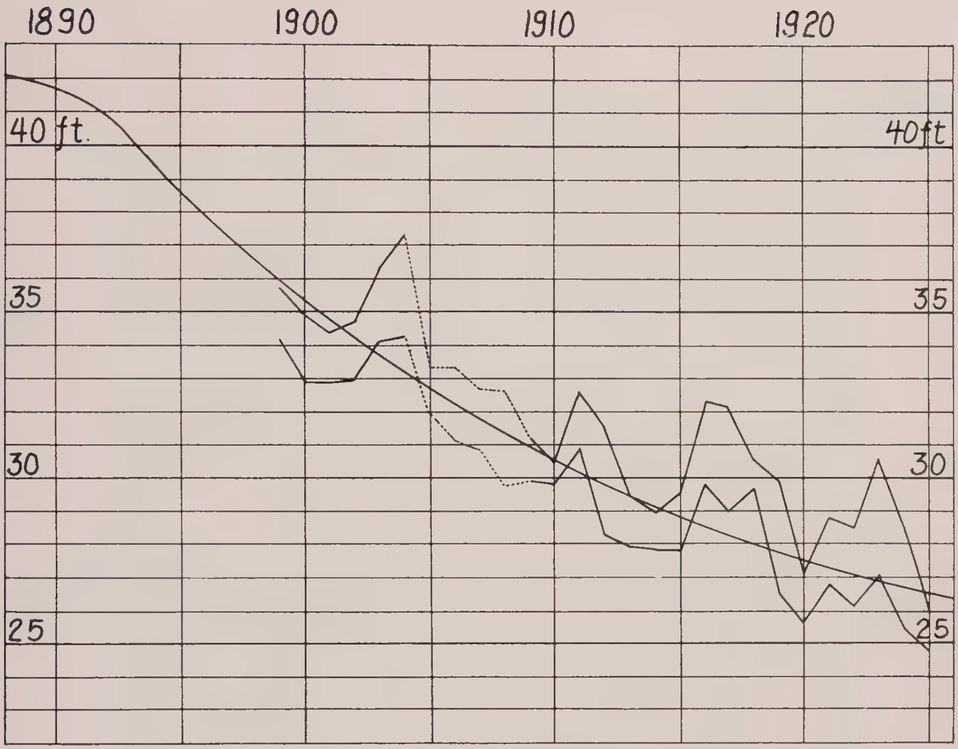

Fig. 10.

on the artesian water-bearing rocks greater than the rate of recharge by absorption in the intake area. At the end of 1925, the head had fallen to a little less than 25 feet. This means that the contact between salt and fresh water has risen from a depth of 1,700 feet below sea level in 1880 to a depth of only 1,000 feet. The new higher level of the contact zone is diagrammatically shown by the line C′-Z′ of Fig. 8. The contact has already risen as high as the bottom of some of the deepest wells and these wells now yield brackish or salt water. Unless overdraft on the artesian supply ceases we may feel sure that more wells will "go salty."

Exotic Trees in Hawaii

By H. L. Lyon

Enterolobium cyclocarpum: This magnificent tree is native in Tropical America and the West Indies. It is known to the outside world principally through the exportation of its timber from Mexico and Central America. Its common names are legion in the countries where it grows and its timber is known in the trade under the names Genisero or Jenisero, Mexican walnut and South American walnut. Many of the names applied to this tree by the aborigines

Fig. 1. *Enterolobium cyclocarpum.* A moderate sized ear-pod tree growing in Thomas Square, Honolulu.

Fig. 2. Leaves, flowers and fruit of the ear-pod tree.

refer to its curiously shaped pods, which resemble the concha or external portion of the human ear. In Hawaii, the tree is popularly known as the Ear-pod and Elephant's ear.

Enterolobium cyclocarpum is a rapid-growing tree with up-standing branches, which carry its broad crown to great height. Its leaves are twice pinnate, the ultimate divisions being very small, oblong leaflets, which are extremely numerous; sometimes as many as 2,000 to the leaf. Its abundant, finely divided, feathery foliage, held so far aloft by strikingly massive branches, gives this tree an air of grace and grandeur not possessed by any other tree in our gardens.

The Ear-pod must have been introduced into these Islands some sixty or seventy years ago, judging by a few huge specimens to be found in old gardens. It has never been planted extensively, however, for there are comparatively few old trees in the Territory. The largest specimen with which we are familiar occurs in Mrs. Foster's garden on Nuuanu Avenue. This tree is over 80 feet tall and its trunk measures 21 feet, 7 inches in circumference, 3 feet from the ground. Another large specimen may be seen just off Keeaumoku Street in the grounds of the Board of Agriculture and Forestry. Its trunk measures 15 feet in circumference, 3 feet from the ground and its far-flung branches extend clear across Keeaumoku Street. There are two fine, but younger, specimens in Thomas Square, one of which is shown in an accompanying illustration. The largest number of Ear-pod trees which we have encountered in any one locality occur in and around Puunene on Maui. From these trees, we secured 250 bags of pods during the last fruiting season.

Strange to say, the Ear-pod had not been tested out as a possible forest tree on our watersheds until very recently. Evidence supplied by some of our experimental plantings clearly indicates that this tree can be used to advantage in the lower zones of our watershed forests. Its rapid growth and the form and stature which it attains render it an ideal component of a mixed forest such as we desire to build. Its big seeds germinate readily, producing at once, large, strong-growing seedlings. This renders it an especially good subject for spot-planting in the open field, as the seedlings quickly over-top the Hilo grass and so require very little subsequent attention. The seedlings are easily handled in the nursery, for they are very resistant to the damping-off fungus and other ills which are prone to take heavy toll among the young seedlings in a nursery. The young trees stand handling and transplanting admirably well. Add to these merits the fact that the trees do remarkably well under the adverse soil conditions existing on our watersheds, and it will be quite evident that the Ear-pod should be given much consideration when formulating planting plans for our new forests.

There seems to be very little information in the literature regarding economic products which may be derived from *Enterolobium cyclocarpum.* A small amount of the timber is evidently being imported into the United States, where it is used as a cabinet wood and for interior decoration. No doubt, its use will become

more general in future years as the supply of the better-known tropical woods is depleted. The quality of the wood apparently varies considerably and is probably much influenced by the conditions under which the tree grew which produced the particular sample examined. The local-grown wood, which has come into our hands, is very soft and easily worked. It has a pretty grain and takes a nice polish. A specimen of "Jenisero," secured from a lumber dealer in San Francisco, is much harder than the Hawaiian-grown wood. The useful purposes which this tree and its products serve in other parts of the world may be learned from the authorities quoted below:

Enterolobium cyclocarpum (Jacq.) Griseb. Fl. Brit. W. Ind. 226. 1860.

Sinaloa to Tamaulipas, Vera Cruz, and Chiapas. Central America, West Indies, and northern South America.

Large unarmed tree, 12 to 30 meters high or larger, with broad spreading crown, the trunk 0.6 to 2.5 meters in diameter; bark rough; leaves bipinnate, the leaflets very numerous, linear-oblong, 10 to 12 mm. long, acute or obtuse; flowers small, white, sessile in dense heads; fruit flat, coiled, 8 to 11 cm. in diameter, dark brown, lustrous; seeds dark brown or black, about 12 mm. long; wood hard, resistant, elastic, grayish tinged with yellow, sometimes livid and mottled.

The tree grows rapidly and makes an excellent shade tree because of the broad top. The large trunks are used for canoes, water troughs, etc., and the wood is very durable in water. It is employed in carpentry and cabinet work. The pods are said to be an excellent feed for cattle, and the seeds as well as the young pods are sometimes cooked to be used for human food. The fruit and bark are rich in tannin. Rose reports that in Sinaloa the bark and fruit are used as a substitute for soap in washing woolen goods and that a syrup made from the bark is used for colds. The fruit is used as a soap substitute in Venezuela also. The gum which exudes from the trunk is employed in Sinaloa as a remedy for bronchitis.—Standley, Paul C., page 391.

Timber known as "guanacaste," "conacaste," "pichwood," "Genizero," and South American walnut has been introduced into the markets of the United States, principally from Mexico and Central America, and is being used to considerable extent in California cities for interior trim in houses and office buildings. The species producing this is *Enterolobium cyclocarpum* Gris., a tree sometimes 125 feet or more in height, with a broad, spreading crown, a thick trunk sometimes 10 feet in diameter, and leaves and fruits similar to the "timbo" of Argentina.

The timber enters the United States markets as roughly hewn logs averaging about 24 inches in diameter and from 10 to 14 feet in length, usually free of defects. There is considerable variation in density of the material, ranging from the consistency of white pine (*Pinus Strobus*) to that of walnut (*Juglans nigra*). The heavier material resembles walnut in general appearance and makes a fairly satisfactory substitute. . . .

Color walnut-brown or with various shadings; sometimes with a reddish tinge in part; luster rather high. Sapwood dull white, merging gradually into the heartwood.

Odor and taste absent or not distinctive.

Very light, soft and spongy to moderately hard and firm. Sp. gr. (air-dry) 0.35 to 0.60. Weight 22 to 37 lbs. per cu. ft. Grain straight to somewhat roey. Texture medium to coarse. Wood very easy to work, harder kinds take good polish, readily seasoned without warping and checking, fairly durable.—Record, Samuel J. and Mell, Clayton D., pp. 205, 206.

Jenisero. "*Enterolobium cyclocarpum.*" A brown, coarse grained cabinet wood from the West Coast of Central America. It is strong and tough and takes a beautiful and lasting polish. Jenisero is generally figured very beautifully and is used to a great extent in the interior finish of office buildings on the Pacific Coast. It is very little used in the Eastern States, but as it is a very plentiful wood, there is no doubt that it will in time become popular there. The Fairmont and Whitcomb Hotels and the Monadnock Building in San Francisco, are finished in Jenisero.—White, C. H., p. 7.

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Potash Fertilization on Ewa Plantation

By W. P. ALEXANDER *

Potash fertilization of the cane has been placed upon a sound basis of control at the Ewa Plantation Company. Investigation was started six years ago and conclusions for individual fields based upon:

(1) Field plot experiments,

(2) Analysis of the soil for potash, and,

(3) Analysis of the crusher juice for potash have provided a practical and working foundation from which it can be decided whether or not the cane requires potash fertilization. The results have governed the application of potash over the plantation so that at the present time there are approximately:

(a) 800 acres or 10 per cent of total area where there is very good evidence that potash is needed in large doses and where returns have been secured from tests ranging from one-third of a ton to two tons of sugar per acre.

(b) 1100 acres or 14 per cent where there is only fair evidence that moderate amounts of potash will benefit the cane, and where returns of less than half a ton of sugar have been obtained.

(c) 1700 acres or 22 per cent where potash is applied in small amounts for insurance purposes. The data, here, are not conclusive one way or the other.

* Head of Department of Agricultural Research and Control, Ewa Plantation Company.

(d) 2500 acres or 32 per cent where no potash is applied, but which is on the border line and must be observed very carefully for signs of potash deficiency.

(e) 900 acres or 11 per cent where potash is not needed, the evidence being good.

(f) 900 acres or 11 per cent where potash is not needed, the evidence being very good.

From the above data one can easily calculate the large financial gain which is the outcome of:

(1) Increased profits due to gains from extra potash fertilization.

(2) Decreased cost of fertilizer, the consequence of not applying potash to 4500 acres which previously received a certain amount in mixed fertilizers.

The inquiry has been thorough and careful, and has made possible a refinement in fertilizer control as regards potash. The expense of the investigation has been small, and because the results were of practical value, the better knowledge of fertilization needs of the cane under varied soil conditions have given profits that could not be expected under the "rule of thumb" regime.

No attempt will be made here to present the voluminous records obtained from:

1536 juice analyses from all fields (excluding Crop 1926),

1006 soil analyses; 753 by Ewa laboratory and 253 by the H. S. P. A. Experiment Station,

45 field experiments harvested from 1922 to 1926 covering 342 acres, having watercourse size plots, ⅓ to ½ acre each.

It is of some scientific interest to see just what data have been obtained upon which to base deductions and therefore certain typical examples of the data will be examined. It must be clearly understood that one has had to deal with the usual amount of experimental error in this investigation and certain contrary results have been secured. Taken as a whole, the findings are consistent and the evidence offered in this review will be given without trying to discuss discordant results. It is the general trend of the project and not specific details which will be presented.

Gains from Potash

Positive response of the cane to potash fertilizer has mainly been confined to fields of a particular alluvial soil type. It is a black adobe heavy clay. Usually poorer drainage and some salt accumulation accompanies this kind of soil.

Grouped below (Table 1) is a study of some of the tests harvested from fields of the so-called "wet" type.

TABLE 1

Cane Yields

Field	Exp. No.	Crop	No. of Plot to Plot Comparison	Lbs. K_2O	Forms	Average Yields per Acre (Tons Cane) Potash Plots	Check Plots	Diff.	Per Cent Diff.
3-A	K-24	1924	30	800	Mol. Ash	87.36	84.41	+ 2.95	+ 3.49
3-A	K-24	1926	30	Residual	Effect	104.73	102.07	+ 2.66	+ 2.61
Average 2 crops						96.05	93.24	+ 2.81	+ 3.01
3-A	K-37	1926	23	250	Pot. Nit.....	89.79	87.16	+ 2.63	+ 3.02
3-A	K-38	1926	11	250	Sul. Pot......	92.10	88.34	+ 3.76	+ 4.26
3-A	K-39	1926	7	500	Sul. Pot......	102.97	89.10	+13.87	+15.57
3-A	K-39	1926	10	250	Sul. Pot......	100.13	89.10	+11.03	+12.38
3-A	K-39	1926	10	100	Sul. Pot......	94.34	89.10	+ 5.24	+ 5.88
3-C	K-16	1923	6	100	Sul. Pot......	84.89	82.86	+ 2.03	+ 2.45
3-C	K-16	1925	6	200	Sul. Pot......	119.08	116.85	+ 2.23	+ 1.91
3-C	K-16	1926	6	200	Sul. Pot......	84.57	80.09	+ 4.48	+ 5.59
Average 3 crops						96.18	93.27	+ 2.91	+ 3.12
3-C	K-33	1925	11	350	Mol. Ash	107.74	105.79	+ 1.95	+ 1.84
3-D	K-40	1926	20	100	Sul. Pot......	70.22	63.26	+ 6.96	+11.00
11	K-8	1923	8	100	Sul. Pot......	86.38	80.51	+ 5.87	+ 7.29
11	K-34	1925	21	400,800	Mol. Ash	103.00	98.68	+ 4.32	+ 4.38
14-B	K-27	1925	2	250	Sul. Pot......	122.68	112.50	+10.18	+ 9.05
20-C	K-32	1925	21	400	Mol. Ash	111.38	110.80	+ 0.58	+ 0.52
Average all experiments						97.59	92.54	+ 5.05	+ 5.46

Potash Applied
Plot 15-K, Field 3-A, showing residual effect from molasses ash. Previous crop 10.65 tons sugar per acre.

No Potash
Plot 14-X, Field 3-A, showing less growth where potash has been withheld. Previous crop 9.55 tons sugar per acre.

It is seen that the small but consistent increases in cane yields are produced with 100 to 800 pounds of potash applied in the form of sulphate, nitrate and molasses ash. The economical amount to apply, the proper time to apply and the best form are questions still unsettled. The gains in cane yield ranged from 2 to 14 tons per acre and averaged 5 tons per acre.

No Potash
Plot 16-X, Field 3-A, showing less growth where no potash was applied.

Potash Applied
Plot 15-K, Field 3-A, showing residual effect from molasses ash.

TABLE 2

Quality Ratio

Field	Exp. No.	Crop	No. of Plot to Plot Comparison	Lbs. K_2O	Forms	Quality Ratio Potash Plots	Check Plots	Diff.	Per Cent Diff.
3-A	K-24	1924	30	800	Mol. Ash	8.01	8.20	+ 0.19	+ 2.32
3-A	K-24	1926	30	Residual	Effect	8.42	8.88	+ 0.46	+ 5.18
Average 2 crops....................................						8.22	8.54	+ 0.32	+ 3.75
3-A	K-37	1926	23	250	Pot. Nit.....	8.52	8.78	+ 0.26	+ 2.96
3-A	K-38	1926	10	250	Sul. Pot......	8.15	8.51	+ 0.36	+ 4.23
3-A	K-39	1926	7	500	Sul. Pot......	8.22	8.54	+ 0.32	+ 3.75
3-A	K-39	1926	10	250	Sul. Pot......	8.36	8.54	+ 0.18	+ 2.11
3-A	K-39	1926	10	100	Sul. Pot......	8.63	8.54	— 0.09	— 1.05
3-C	K-16	1923	6	100	Sul. Pot......	9.02	9.15	+ 0.13	+ 1.42
3-C	K-16	1925	6	200	Sul. Pot......	10.11	10.71	+ 0.60	+ 5.60
3-C	K-16	1926	6	200	Sul. Pot......	8.22	8.43	+ 0.21	+ 2.49
Average 3 crops....................................						9.12	9.43	+ 0.31	+ 3.29
3-C	K-33	1925	11	350	Mol. Ash	9.90	10.44	+ 0.54	+ 5.17
3-D	K-40	1926	20	100	Sul. Pot......	8.34	8.53	+ 0.19	+ 2.23
11	K-8	1923	8	100	Sul. Pot......	9.26	9.43	+ 0.17	+ 1.80
11	K-34	1925	21	400,800	Mol. Ash	7.79	7.80	+ 0.01	+ 0.13
14-B	K-27	1925	2	250	Sul. Pot......	8.29	8.56	+ 0.27	+ 3.15
20-C	K-32	1925	21	400	Mol. Ash	7.42	7.70	+ 0.28	+ 3.64
Average all experiments.............................						8.54	8.80	+ 0.26	+ 2.95

Evidence presented here (Table 2) shows that the sucrose content of the cane may be improved by potash fertilization. At first, in 1922-23 the preliminary findings showing that the quality ratio was better in the potash plots was questioned, as such results were contrary to the published data* on the subject. However, further results corroborated the original conclusions as may be seen above.

Graph 1, a plot-to-plot comparison of Experiment K-24, is an example of how very regular such a low quality ratio may be with an experiment. All tests were not as consistent as this, but the general trend is for cane grown on this type of soil to not only have more cane, but almost a proportionate increase in the sucrose content. Such a benefit from potash fertilization was unexpected and has been very gratifying, inasmuch as every effort is being made at Ewa Plantation to better the quality of the cane.

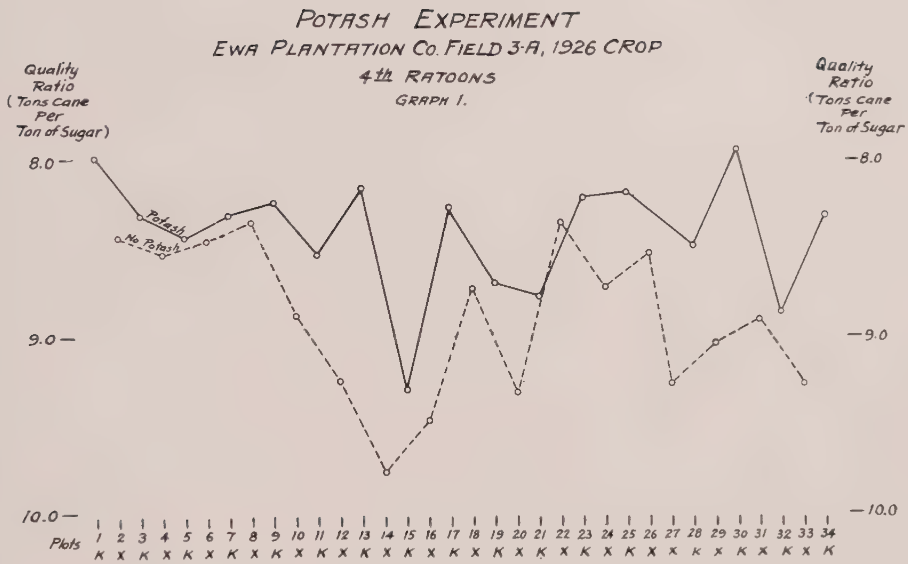
TABLE 3

Sugar Yields

Field	Exp. No.	Crop	No. of Plot to Plot Comparison	Lbs. K_2O	Forms	Yields per Acre (Tons Sugar) Potash Plots	Check Plots	Diff.	Per Cent Diff.
3-A	K-24	1924	30	800	Mol. Ash	10.91	10.29	+ 0.62	+ 6.03
3-A	K-24	1926	30	Residual	Effect	12.44	11.49	+ 0.95	+ 8.27
Average 2 crops						11.68	10.89	+ 0.79	+ 7.25
3-A	K-37	1926	23	250	Pot. Nit.....	10.54	9.93	+ 0.61	+ 6.14
3-A	K-38	1926	10	250	Sul. Pot......	11.30	10.38	+ 0.92	+ 8.86
3-A	K-39	1926	7	500	Sul. Pot......	12.52	10.43	+ 2.09	+20.04
3-A	K-39	1926	10	250	Sul. Pot......	11.98	10.43	+ 1.55	+14.86
3-A	K-39	1926	10	100	Sul. Pot......	10.93	10.43	+ 0.50	+ 4.79
3-C	K-16	1923	6	100	Sul. Pot......	9.42	9.06	+ 0.36	+ 3.97
3-C	K-16	1925	6	200	Sul. Pot......	11.78	10.91	+ 0.87	+ 7.97
3-C	K-16	1926	6	200	Sul. Pot......	10.29	9.50	+ 0.79	+ 8.32
Average 3 crops						10.50	9.82	+ 0.68	+ 6.92
3-C	K-33	1925	11	350	Mol. Ash	10.88	10.13	+ 0.75	+ 7.40
3-D	K-40	1926	20	100	Sul. Pot......	8.42	7.42	+ 1.00	+13.48
11	K-8	1923	8	100	Sul. Pot......	9.33	8.54	+ 0.79	+ 9.25
11	K-34	1925	21	400,800	Mol. Ash	13.22	12.65	+ 0.57	+ 4.51
14-B	K-27	1925	2	250	Sul. Pot......	14.80	13.14	+ 1.66	+12.63
20-C	K-32	1925	21	400	Mol. Ash	15.01	14.39	+ 0.62	+ 4.31
Average all experiments						11.49	10.57	+ 0.92	+ 8.70

The increased yield of sugar per acre (see Table 3) in the potash plots averaged almost one ton of sugar. The different tests showed various increases but with few exceptions all experiments installed in this soil type have showed that potash could be applied with a profit. At present prices, 100 pounds of K_2O costs not over eight dollars per acre applied.

* *The Hawaiian Planters' Record*, Vol. XXVII, p. 117; Vol. XXX, p. 60.



Graph 1.

TABLE 4

Soil Analysis—Per Cent Potash in Soil

(Analyses by Ewa Laboratory and H. S. P. A. Experiment Station)
1922-1926

Field	HCl Sol.	Citrate Sol.
3-A	0.18	0.018
3-C	0.20	0.018
3-D	0.26	0.013
11	0.17	0.015
14-B	0.18	0.012
20-C	0.30	0.014
	——	——
Average	0.22	0.015

Analyses of the soil from the experiments under consideration (Table 4) were made by the Ewa laboratory and the Experiment Station of the H. S. P. A. They show a deficiency of potash in the soil from these experiments with an average of 0.22 per cent K_2O as shown by hydrochloric acid digestion and 0.015 per cent K_2O by the citrate acid method. The results from the former method seem to be less consistent than from the latter where a difference of only 0.005 is found between the high and low analyses.

Juice Analysis

To supplement the data obtained from field experiments and soil analyses the per cent of potash in the crusher juice is secured. The Sherrill method* was used and when results are interpreted it must be remembered that the figures obtained

* *The Hawaiian Planters' Record*, Volume XXVII, p. 112, April, 1923.

are not very exact, but are only indicative. The reason for using such a questionable method is that it is simple and can very easily be adopted by the routine of the ordinary plantation sugar laboratory. It is better than no information at all. The following results (Table 5) were obtained from some of the experiments where potash was needed:

TABLE 5

Per Cent Potash in Crusher Juice

Field	Exp. No.	Crop	No. of Samples	Lbs. K_2O	Forms	K_2O in Crusher Juice: Potash Plots	Check Plots	Diff.
3-A	K-24	1924	Composited	800	Mol. Ash.......	0.73	0.36	+0.37
3-A	K-37	1926	28	250	Pot. Nit........	0.19	0.11	+0.08
3-A	K-38	1926	39	250	Sul. Pot........	0.36	0.30	+0.06
3-C	K-16	1923	14	100	Sul. Pot........	0.75	0.55	+0.20
3-C	K-16	1925	12	200	Sul. Pot........	0.45	0.35	+0.10
3-C	K-16	1926	14	200	Sul. Pot........	0.22	0.47	—0.25
Average 3 crops						0.47	0.46	+0.01
3-C	K-33	1925	14	350	Mol. Ash.......	0.44	0.45	—0.01
3-D	K-40	1926	45	500, 250, 200	Sul. Pot........	0.48	0.35	+0.13
11	K-34	1925	32	400, 800	Mol. Ash.......	0.93	0.74	+0.19
14-B	K-27	1925	3	250	Sul. Pot........	0.83	0.58	+0.25
20-C	K-32	1925	22	400	Mol. Ash.......	0.32	0.34	—0.02
Average all tests						0.52	0.42	+0.10

Tests Showing no Response or Loss for Potash Fertilization

It has been shown that there are soil conditions where potash fertilizer will be very profitable. The opposite also seems to be true on certain other types of soil found at Ewa Plantation. An examination of the fields where these tests are located shows that the lime content is very high. They belong to the so-called coral or semi-coral type, i.e., the soil has been washed down from the mountains upon the disintegrated coral.

There are given below (Table 6) the yields, soil and juice analyses from a group of tests where potash failed to improve cane yields or the quality of the juice. It will be noted that potash fertilization tends to depress cane yields.

TABLE 6

Cane Yields

Field	Exp. No.	Crop	No. of Plot to Plot Comparison	Lbs. K_2O	Forms	Yields per Acre (Tons Cane): Potash Plots	Check Plots	Diff.	Per Cent Diff.
19-F	K-7	1923	11	100	Sul. Pot......	136.03	146.84	—10.81	— 7.36
19-F	K-7	1925	8	100	Sul. Pot......	141.26	141.99	— 0.73	— 0.51
19-F	K-7	1926	7	100	Sul. Pot......	90.33	95.21	— 4.88	— 5.13
Average 3 crops						122.54	128.01	— 5.47	— 4.27
22-A	K-23	1924	8	100	Sul. Pot......	85.14	86.71	— 1.57	— 1.81
22-A	K-23	1925	4	100	Sul. Pot......	81.96	84.23	— 2.27	— 2.70
Average 2 crops						83.55	85.47	— 1.92	— 2.25
22-B	K-18	1923	10	200	Sul. Pot......	47.71	52.00	— 4.29	— 8.25
Average all experiments						97.07	101.16	— 4.09	— 4.04

The quality ratios from the potash and check plots as given herewith do *not* show that potash has influence on the sucrose content one way or the other if cane yields are the same or poorer.

TABLE 7

Quality Ratio

Field	Exp. No.	Crop	No. of Plot to Plot Comparison	Lbs. K_2O	Forms	Quality Ratio Potash Plots	Check Plots	Diff.	Per Cent Diff.
19-F	K-7	1923	11	100	Sul. Pot......	9.89	9.78	— 0.11	— 1.12
19-F	K-7	1925	8	100	Sul. Pot......	9.19	9.27	+ 0.08	+ 0.86
19-F	K-7	1926	7	100	Sul. Pot......	9.74	9.74	....	....
Average 3 crops......						9.61	9.60	— 0.01	— 0.10
22-A	K-23	1924	8	100	Sul. Pot......	9.51	9.62	+ 0.11	+ 1.14
22-A	K-23	1925	4	100	Sul. Pot......	8.11	8.00	— 0.11	— 1.38
Average 2 crops......						8.81	8.81	....	....
22-B	K-18	1923	10	200	Sul. Pot......	10.20	10.34	+ 0.14	+ 1.35
Average all experiments......						9.44	9.46	+ 0.02	+ 0.21

Applications of potash can be dispensed with under these conditions (Table 7).

TABLE 8

Sugar Yields

Field	Exp. No.	Crop	No. of Plot to Plot Comparison	Lbs. K_2O	Forms	Yields per Acre (Tons Sugar) Potash Plots	Check Plots	Diff.	Per Cent Diff.
19-F	K-7	1923	11	100	Sul. Pot......	13.75	15.01	— 1.26	— 8.39
19-F	K-7	1925	8	100	Sul. Pot......	15.37	15.32	+ 0.05	+ 0.33
19-F	K-7	1926	7	100	Sul. Pot......	9.27	9.78	— 0.51	— 5.21
Average 3 crops......						12.80	13.37	— 0.57	— 4.26
22-A	K-23	1924	8	100	Sul. Pot......	8.95	9.01	— 0.06	— 0.67
22-A	K-23	1925	4	100	Sul. Pot......	10.11	10.53	— 0.42	— 3.99
Average 2 crops......						9.53	9.77	— 0.24	— 2.46
22-B	K-18	1923	10	200	Sul. Pot......	4.68	5.03	— 0.35	— 6.96
Average all experiments......						10.36	10.78	— 0.42	— 3.90

Soil analyses made from the above tests are high in potash, as shown from these data (Table 9).

TABLE 9

Soil Analysis—Per Cent Potash in Soil

Field	HCl Sol.	Citrate Sol.
19-F	1.19	0.078
22-A	0.29	0.024
22-B	0.39	0.040
Average	0.62	0.047

TABLE 10

Juice Analysis—Per Cent Potash in Crusher Juice

						K_2O in Crusher Juice		
			No. of			Potash	Check	
Field	Exp. No.	Crop	Samples	Lbs. K_2O	Forms	Plots	Plots	Diff.
19-F	K-7	1923	13	100	Sul. Pot.........	1.16	1.21	—0.05
19-F	K-7	1925	13	100	Sul. Pot.........	1.52	1.52	......
Average 2 crops......						1.34	1.37	—0.03
22-A	K-23	1925	21	100	Sul. Pot.........	1.40	1.50	—0.10
Average all tests......						1.36	1.41	—0.05

The crusher juice (Table 10) reflects the high content of potash, as shown by soil samples. The average is 1.4 per cent K_2O.

Fields Which May or May Not Respond to Potash

The bulk of the fields lie between the above two extremes, namely, the adobe type needing potash and the coral type where potash is not wanted. Just how long potash fertilizer can be held off on these fields without depletion of the natural reserve remains to be seen. There is a chance that before long potash fertilizer will be needed again. The amount removed during each crop is very large. Probably between 200 and 300 pounds of K_2O is taken up from the soil in the heaviest cane crops. This cannot go on forever and to guard against injury to the fertility of the soil, experimental plots with and without potash are continued indefinitely.

Examples of tests where negative results have been secured, but where potash is sometimes applied to surrounding fields for insurance purposes, is given below (Table 11):

TABLE 11

Cane Yields

Field	Exp. No.	Crop	No. of Plot to Plot Comparison	Lbs. K_2O	Forms	Yields per Acre (Tons Cane) Potash Plots	Check Plots	Diff.	Per Cent Diff.
A	K-2	1922	13	100	Sul. Pot......	59.79	59.21	+ 0.58	+ 0.98
A	K-2	1924	13	100	Sul. Pot......	107.56	108.53	— 0.97	— 0.89
A	K-2	1926	13	100	Sul. Pot......	110.09	107.52	+ 2.57	+ 2.39
Average 3 crops						92.48	91.75	+ 0.73	+ 0.80
1-A	K-29	1925	21	200	Sul. Pot......	134.27	133.60	+ 0.67	+ 0.50
1-E	K-36	1926	44	250	Sul. Pot......	113.22	111.66	+ 1.56	+ 1.40
2-A	K-31	1925	5	100	Sul. Pot......	137.81	137.09	+ 0.72	+ 0.53
7	K-1	1922	9	100	Sul. Pot......	92.80	94.99	— 2.19	— 2.31
7	K-1	1924	9	100	Sul. Pot......	109.41	108.70	+ 0.71	+ 0.65
7	K-1	1925	12	100	Sul. Pot......	91.01	90.69	+ 0.32	+ 0.35
Average 3 crops						97.74	98.13	— 0.39	— 0.40
19-B	K-30	1925	7	100	Sul. Pot......	130.21	129.11	+ 1.10	+ 0.85
19-D	K-14	1923	23	50	Sul. Pot......	82.41	83.85	— 1.44	— 1.72
19-D	K-14	1924	24	100	Sul. Pot......	76.37	75.85	+ 0.52	+ 0.69
19-D	K-14	1926	25	100	Sul. Pot......	74.73	76.70	— 1.97	— 2.57
Average 3 crops						77.84	78.80	— 0.96	— 1.22
25-A	K-21	1924	12	100	Sul. Pot......	113.99	114.14	— 0.15	— 0.13
25-A	K-21	1926	8	100	Sul. Pot......	92.45	93.07	— 0.62	— 0.67
Average 2 crops						103.22	103.61	— 0.39	— 0.38
Average all experiments						101.74	101.65	+ 0.09	+ 0.09

A study of the above compilation (Table 11) shows that there is no pronounced gain or loss in cane yields due to potash fertilization on these eight representative fields scattered from one end of the plantation to the other, excluding the adobe and coral fields. Average cane yields are within experimental error.

TABLE 12

Quality Ratio

Field	Exp. No.	Crop	No. of Plot to Plot Comparison	Lbs. K_2O	Forms	Quality Ratio Potash Plots	Check Plots	Diff.	Per Cent Diff.
A	K-2	1922	13	100	Sul. Pot......	8.55	8.55	....	....
A	K-2	1924	13	100	Sul. Pot......	8.32	8.48	+ 0.16	+ 1.89
A	K-2	1926	13	100	Sul. Pot......	8.76	8.72	— 0.04	— 0.46
Average 3 crops						8.54	8.58	+ 0.04	+ 0.47
1-A	K-29	1925	21	200	Sul. Pot......	8.12	8.21	+ 0.09	+ 1.10
1-E	K-36	1926	44	250	Sul. Pot......	8.04	8.10	+ 0.06	+ 0.74
2-A	K-31	1925	5	100	Sul. Pot......	8.21	8.29	+ 0.08	+ 0.97
7	K-1	1922	9	100	Sul. Pot......	8.08	8.17	+ 0.09	+ 1.10
7	K-1	1924	9	100	Sul. Pot......	10.02	10.13	+ 0.11	+ 1.09
7	K-1	1925	12	100	Sul. Pot......	8.09	8.08	— 0.01	— 0.12
Average 3 crops						8.73	8.79	+ 0.06	+ 0.68
19-B	K-30	1925	7	100	Sul. Pot......	7.85	7.90	+ 0.05	+ 0.63
19-D	K-14	1923	23	50	Sul. Pot......	10.29	10.22	— 0.07	— 0.68
19-D	K-14	1924	24	100	Sul. Pot......	7.94	7.97	+ 0.03	+ 0.38
19-D	K-14	1926	25	100	Sul. Pot......	8.07	8.08	+ 0.01	+ 0.12
Average 3 crops						8.77	8.76	— 0.01	— 0.11
25-A	K-21	1924	12	100	Sul. Pot......	7.62	7.58	— 0.04	— 0.53
25-A	K-21	1926	8	100	Sul. Pot......	8.89	9.00	+ 0.11	+ 1.22
Average 2 crops						8.26	8.29	+ 0.03	+ 0.36
Average all experiments						8.46	8.50	+ 0.04	+ 0.47

Potash failed to improve sucrose content where no gains in cane yields were secured (Table 12). The quality ratios of the potash-treated and untreated plots are remarkably close.

TABLE 13

Sugar Yields

Field	Exp. No.	Crop	No. of Plot to Plot Comparison	Lbs. K_2O	Forms	Yields per Acre (Tons Sugar) Potash Plots	Check Plots	Diff.	Per Cent Diff.
A	K-2	1922	13	100	Sul. Pot......	6.99	6.93	+ 0.06	+ 0.87
A	K-2	1924	13	100	Sul. Pot......	12.79	12.73	+ 0.06	+ 0.47
A	K-2	1926	13	100	Sul. Pot......	12.57	12.33	+ 0.24	+ 1.95
Average 3 crops						10.78	10.66	+ 0.12	+ 1.13
1-A	K-29	1925	21	200	Sul. Pot......	16.54	16.27	+ 0.27	+ 1.65
1-E	K-36	1926	44	250	Sul. Pot......	14.08	13.78	+ 0.30	+ 2.18
2-A	K-31	1925	5	100	Sul. Pot......	16.79	16.54	+ 0.25	+ 1.51
7	K-1	1922	9	100	Sul. Pot......	11.49	11.63	— 0.14	— 1.20
7	K-1	1924	9	100	Sul. Pot......	10.92	10.73	+ 0.19	+ 1.77
7	K-1	1925	12	100	Sul. Pot......	11.25	11.22	+ 0.03	+ 0.27
Average 3 crops						11.22	11.19	+ 0.03	+ 0.27
19-B	K-30	1925	7	100	Sul. Pot......	16.59	16.34	+ 0.25	+ 1.53
19-D	K-14	1923	23	50	Sul. Pot......	8.01	8.20	— 0.19	— 2.32
19-D	K-14	1924	24	100	Sul. Pot......	9.62	9.52	+ 0.10	+ 1.05
19-D	K-14	1926	25	100	Sul. Pot......	9.26	9.49	— 0.23	— 2.42
Average 3 crops						8.96	9.07	— 0.11	— 1.21
25-A	K-21	1924	12	100	Sul. Pot......	14.96	15.06	— 0.10	— 0.66
25-A	K-21	1926	8	100	Sul. Pot......	10.40	10.34	+ 0.06	+ 0.58
Average 2 crops						12.68	12.70	— 0.02	— 0.16
Average all experiments						12.15	12.07	+ 0.08	+ 0.66

Negative results are shown for the majority of these tests (Table 13), although some of the areas such as A Field and Fields Nos. 1-E, 2-A and 19-B are examples of fields that are on the border line, and potash is being applied to the surrounding cane in order that no chances may be taken that the cane will suffer from potash starvation. Soil from these fields gave the following analyses for potash:

TABLE 14

Soil Analysis—Per Cent Potash in Soil

Field	HCl Sol.	Citrate Sol.
A	0.34	0.031
1-A	0.33	0.020
1-E	0.33	0.027
2-A	0.27	0.014
7	0.27	0.019
19-B	0.30	0.022
19-D	0.22	0.031
25-A	0.20	0.043
Average	0.28	0.026

Juice Analysis

The juice from the same fields showed the results shown in Table 15, giving an average of 0.9 per cent K_2O in the crusher juice.

TABLE 15

Per Cent Potash in Crusher Juice

Field	Exp. No.	Crop	No. of Samples	Lbs. K_2O	Forms	K_2O in Crusher Juice Potash Plots	Check Plots	Diff.
A	K-2	1926	35	100	Sul. Pot........	0.78	0.65	+0.13
1-A	K-29	1925	55	200	Sul. Pot........	0.58	0.64	—0.06
1-E	K-36	1926	48	250	Sul. Pot........	1.19	1.26	—0.07
2-A	K-31	1925	11	100	Sul. Pot........	0.96	0.93	+0.03
7	K-1	1924	Composited	100	Sul. Pot........	0.49	0.49	......
7	K-1	1925	45	100	Sul. Pot........	0.57	0.46	+0.11
Average 2 crops						0.53	0.48	+0.05
19-B	K-30	1925	9	100	Sul. Pot........	0.83	0.73	+0.10
19-D	K-14	1924	34	100	Sul. Pot........	1.54	1.49	+0.05
25-A	K-21	1924	Composited	100	Sul. Pot........	0.51	0.73	—0.22
25-A	K-21	1926	27	100	Sul. Pot........	1.36	1.14	+0.22
Average 2 crops						0.94	0.94	......
Average all tests						0.88	0.85	+0.03

CORRELATION OF DIFFERENT FACTORS

The data reviewed in the preceding pages are summarized below:

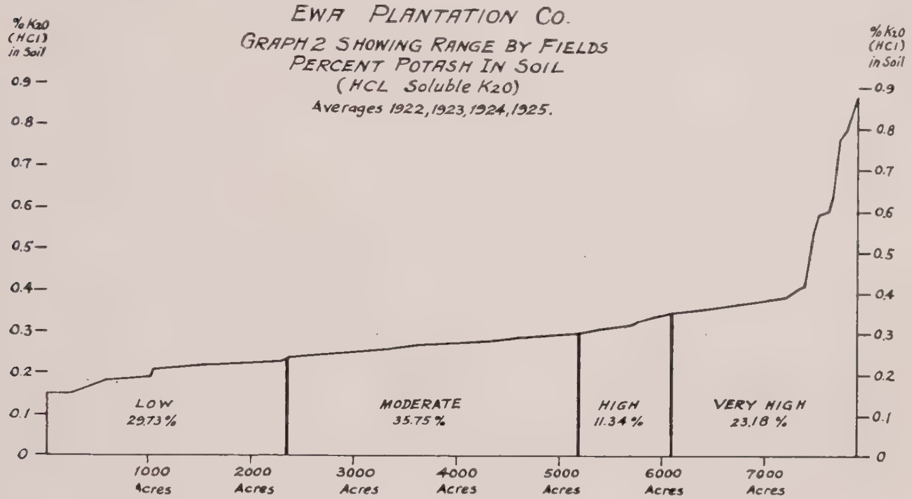
	Soil Type	Average Gain or Loss Cane	Q. R.	Sugar	K_2O in Soil HCl	Cit.	K_2O in Crusher Juice
Gain for Potash.....	Adobe Poor Drained......	+5.05	+0.26	+0.92	0.22%	0.015%	0.42%
No Gain for Potash..	Coral or Semi-coral.......	—4.09	+0.02	—0.42	0.62%	0.047%	1.41%
Negative Results More Data Needed for Further Crops...	General Ewa and Red Soil.	+0.09	+0.04	+0.08	0.28%	0.026%	0.85%

After ironing out all the inconsistences by averages, the direct correlation as exhibited in the above figures between cane yields, soil analysis, and juice analysis, furnish one with a proof that in the main it is possible to rely on these factors for control of potash fertilization.

Results Applied to Field Practice

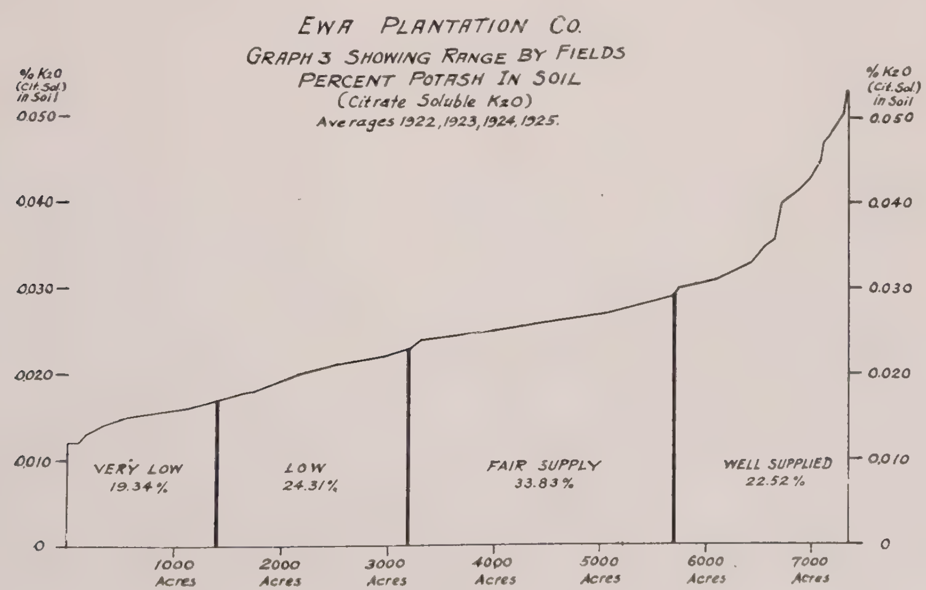
A soil survey of the plantation has been used in conjunction with the field experiments. Every off season the laboratory analyzes from 150 to 200 soil

samples. The Experiment Station of the H. S. P. A. cooperated in making the preliminary soil survey. The range of potash in the soil from different fields is shown on Graphs 2 and 3.



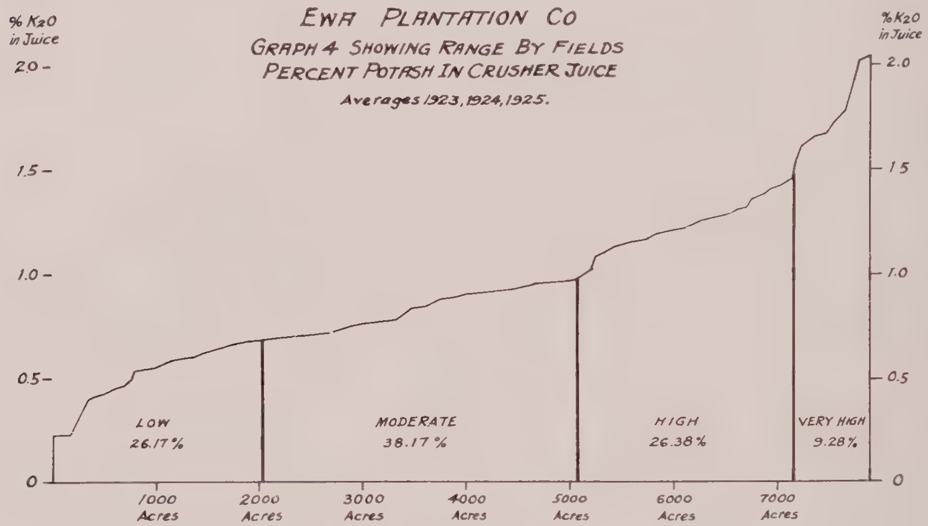
Graph 2.

During four crops the potash content of the crusher juice has been obtained. By procuring a continuous sample of the juice at the mill, it is believed that one is able to obtain a good approximation of the per cent of potash present in the cane grown from a particular field or section of a field. If the potash in the juice is high, the theory is that the soil contains a plentiful supply of potash and where there is little potash in the juice, there is a deficiency of potash in the soil. The information secured in this way has been fairly satisfactory if interpreted in



Graph 3.

light of field tests and correlated with soil analysis. By itself, it probably has little value. Practically every field has had the juice tested twice (1923-1925 or 1924-1926) and on the whole the relative standing of potash in the soil as represented by crusher juice samples has furnished information to be used to help decide potash fertilizer practice. The range of K_2O in the juice is given in Graph 4.



Graph 4.

Certain arbitrary standards have been used to classify the fields as to their potash content (Table 16). They are tentative and may be changed as more data are secured.

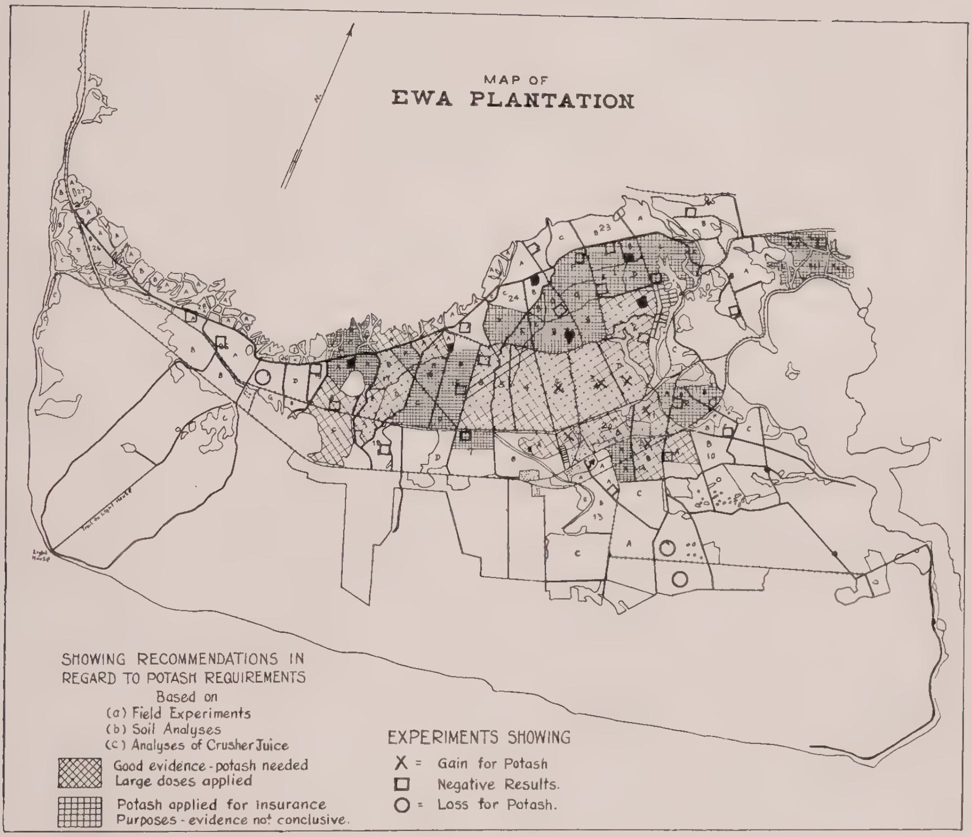
TABLE 16

	Potash in Soil		Potash in
	HCl	Citrate	Juice
Very Low................	Below 0.20	Below 0.017	Below 0.50
Low	0.20–0.25	0.017–0.023	0.50–0.70
Moderate	0.25–0.30	0.023–0.030	0.70–1.00
High	0.30–0.35	0.030–0.040	1.00–1.50
Very High...............	Above 0.35	Above 0.040	Above 1.50

With this data in hand a map of the plantation has been compiled giving the recommendations as regards potash fertilizer requirements.

SUMMARY

1. An endeavor has been made to show how it is possible for the practical plantation man to base recommendations for potash fertilization on a correlation of the three factors—field plot tests which are most important; soil analysis which must be interpreted liberally; and juice analysis which may be subject to considerable variation.



2. Potash fertilization has increased cane yields at Ewa. This increase in cane yield was often accompanied by an improvement in sucrose content, making a double benefit. At present prices extra applications of sulphate of potash, potash nitrate, and molasses ash proved profitable.

3. The area at Ewa where potash is certain to be needed by the cane is limited. On other sections small doses may be applied for insurance purposes or a saving may be effected by applying no potash at all.

4. Safety demands that potash be applied when soil shows less than 0.020 per cent citrate soluble K_2O. Response seems certain when 0.015 per cent K_2O is found in the soil.

5. Juice analysis of the cane ground at the mill furnishes a simple method of determining potash but is a poorer index of the relative amount of potash in the soil and should be used with caution. Juice analyzing with a 0.50 per cent K_2O or less indicated that the soil upon which the cane was grown was weak in potash. A danger mark seemed to be 0.70 per cent K_2O.

Remarks on the Genera of Spear-Bearing Nematodes Found in Hawaii, With a Table for Their Identification

By Gertrude Henderson

For economic reasons it is necessary to identify the nematodes found inhabiting and surrounding plants in the field and for this purpose these so-called "free living" nematodes may be subdivided into three classes:

1. Nematodes possessing a spear-like piercing armature situated in the pharyngeal cavity.
2. Nematodes possessing a pharyngeal tooth or teeth.
3. Nematodes entirely devoid of pharyngeal armature.

This classification is based upon the fundamental differences in anatomical structure and their relationships to the life habits and functional effects produced.

A variety of classifications already exists, but for agricultural purposes this method may be found simplest and most satisfactory as the spear-bearing group are of such enormous economic importance on account of their highly destructive action upon plants.

The difficulties of taxonomic investigation have been enormously increased by reason of the absence of a really satisfactory technique and because of the relative scarcity of literature dealing with this work.

From time to time individual works have been published dealing with this subject, but as yet no one has attempted to consider the entire genera as a whole and for this reason, in order to facilitate systematic classification, a generic reference table has been compiled including all spear-bearing nematodes so far as they are known to the writer.

This table is based upon the findings of Bastian, Cobb, Microletsky and others, and although by no means complete, it has proved of considerable value in our own taxonomic work and will be published in this issue.

From the table it may be seen that the numbers of spear-bearing genera assume considerable proportions and their economic significance may be more fully realized when the function and highly destructive effects of the spear-like armature is appreciated.

The spear is a sharply pointed tubular structure communicating directly with the oesophagus and is situated in the floor of the pharyngeal cavity.

The entire organ is protusile and is controlled by the rythmic action of a set of muscular structures to which it is attached and by means of which its powerful piercing action is effected.

The spear itself may present a variety of structural differences according to the species of nematode under consideration. It is a highly chitinized, hollow tube, and is believed solely instrumental in penetrating the hardened exterior of such objects (presumably plants) as the nematode desires to pierce either for purposes of nourishment or actual habitation.

The commonest example of this is found in the widespread destructive attack so frequently present in our commonest plants. The oval spear punctures the roots, effects an entrance and eventually the entire organism is installed within the root tissues themselves. The extreme seriousness of such an invasion and the subsequent depreciation of tissue vitality is apparent even to the most uninformed.

Apart from the seriousness of the mere mechanical invasion, there are the additional factors of toxin formation, bacterial infection and fungoid infestation to be considered. Each in itself is of grave importance and each may in turn jeopardize the life of the plant affected.

Given suitable conditions there is no reason why all four should not proceed symbiotically in perfect unison and rapidly produce destruction of the entire root system.

The actual nematode punctures in themselves produce a local weakening of the root vitality and afford easy access and suitable environment for the countless myriads of bacteria and fungi invariably associated with soils of every description.

An appreciation of these parasitic conditions may in part explain the frequency and persistence of such enormous root mortality. By reason of its persistence, this mortality has come to be regarded by many as an inevitable sequence of normal plant development. That such an idea is erroneous may be stated without trepidation. Given suitable environment, freedom from organismal infestation, sufficient nourishment, and comparatively sterile conditions, a normal, healthy sugar cane plant produces roots of good vitality and persistence.

The extensive primary root system, relieved from the necessity of continually producing fresh roots to replace diseased areas, develops normally and affords a proper equilibrium for the development and vitality of the aerial portion of the entire plant system.

Generic Reference Table of Spear-bearing Nematodes

1. 46 Spear with the base distinctly enlarged, consisting of either a single structure or of three structures more or less amalagamated together distally.
2. 9 Spear consisting of three pieces either separate or fused together at their distal ends, (rather indefinite).
3. 4 Spear apparently consisting of three separate spines; "Kappchen" present (spear cap); oesophagus muscular. . . . . *Diphtherophora.*
4. 3 Spear consisting of three pieces fused together apically, and with trifurcate base.
5. 6 Oesophagus with a distinct median bulb and an enlarged posterior portion; base of spear with three distinct swellings. . . . . *Tylopharynx.*
6. 5 Oesophagus without median bulb, only gradually enlarged posteriorly; spear split at base.
7. 8 Spear with a "Kappchen" (spear cap). . . . . *Tylolaimorphus.*
8. 7 Spear without a "Kappchen" (spear cap). . . . . *Tylencholaimus.*
9. 2 Spear formed of one piece, base distinctly enlarged.
10. 11 Cuticle with very distinct rings or reticulations broken or complete; spear strong and generally long (1/6 to 1/9 of body length). . . . . *Hoplolaimus.*
11. 10 Cuticle without distinct rings or reticulations.
12. 13 Spear massive, distinctly divided into two parts, the anterior half being chitinous, the basal half transparent, the base not very distinctly enlarged. . . . . *Nemonchus.*

13. 12 Spear not so massive and not divided into two parts.
14. 17 Oesophagus without a median bulb and with only a slight, gradual enlargement posteriorly.
15. 16 Spear very long and slender; oesophagus cylindrical or subcylindrical....*Xiphinema.*
16. 15 Spear shorter and thicker; oesophagus distinctly narrowed in middle..*Tylencholaimus.*
17. 14 Oesophagus with median bulbous swelling.
18. 21 Spear with a "Kappchen" (spear cap).
19. 20 Spear long and slender (¼ length of oesophagus), basal bulb small; anterior oesophageal swelling long; pharynx simple........................*Paratylenchus.*
20. 19 Spear much shorter, basal bulb large; pharynx apparently chitinized on apical half .... *Tylenchorhynchus.*
21. 18 Spear without a "Kappchen" (spear cap).
22. 23 Spear short, thick, apparently attached to the side of the wall of pharynx, apex slightly enlarged, base swollen and oblique..........................*Archionchus.*
23. 22 Spear free from the base, not enlarged at apex, base not oblique.
24. 39 Oesophagus with a distinct median bulb and a distinct posterior swelling.
25. 28 Anteriorly with four large, distinct bristles or setae; bursa trapezoid.
26. 27 Cuticle prominently and longitudinally striate..........................*Atylenchus.*
27. 26 Cuticle not prominently and longitudinally striate.....................*Eutylenchus.*
28. 25 Anteriorly without setae or bristles.
29. 30 Excretory pore behind the middle of body; adult female greatly enlarged.*Tylenchulus.*
30. 29 Excretory pore before middle of body.
31. 32 Oesophagus behind bulb indistinct, appearing as if intestine joined bulb..*Aphelenchus.*
32. 31 Oesophagus behind bulb distinct.
33. 34 Amphids large, oval, deep, often protruded (especially when fixed with Flemming's solution) .... *Triplonchium.*
34. 33 Amphids small, more obscure, not protruded.
35. 36 Males without bursa; adult females greatly swollen and incapable of movement.... *Heterodera.*
36. 35 Males with Bursa; adult females not greatly swollen, capable of movement.
37. 38 Bursa lobate; spear very long (1/3 to 1/5 length of oesophagus)......*Dolichodorus.*
38. 37 Bursa plain; spear smaller (1/5 to 1/31 length of oesophagus)..........*Tylenchus.*
39. 24 Oesophagus without a median bulb.
40. 41 Spear very small or vestigial....................*Aphelenchulus, Tylencholaimellus.*
41. 40 Spear well developed.
42. 43 Spear trifurcate at base, or basal half considerably larger than distal half, subcylindrical.. *Tylencholaimus.*
43. 42 Spear bulbous at base.
44. 45 Spear long and thin; amphid small or absent; "Kappchen" (spear cap) present .... *Paratylenchus.*
45. 44 Spear small, amphid large, oval, amphid chamber deep, amphid often protruding, apparently no "Kappchen" (spear cap)..........................*Triplonchium.*
46. 1 Spear composed of a single hollow piece, slightly and gradually enlarged to base, base truncate, not swollen or enlarged or produced into prongs.
47. 48 Oesophagus with a distinct median bulb; excretory pore present...........*Isonchus.*
48. 47 Oesophagus without a distinct median bulb; excretory pore absent.
49. 50 Anterior portion of pharynx large, cup shape, supported with radiating chitinous ribs or other structures, sometimes beset with small teeth...............*Actinolaimus.*
50. 49 Pharynx anteriorly small, without such armature.
51. 52 Spear very long, slender and flexible................................*Trichodorus.*
52. 51 Spear thick, not flexible, proportionally shorter.......................*Dorylaimus.*
a b Spear long, needle-like..*Longidorus.*
b a Spear not so long and needle-like, more spine-like.
c d Spear gradually enlarging from middle to base........................*Doryllium.*

d	c	Spear without such enlargement of the base.
e	f	Oesophagus considerably swollen at the anterior end................. *Dorylaimellus.*
f	e	Oesophagus not swollen at the anterior end.
g	h	Lip region discoid, expanded, sucker-like............................ *Discolaimus.*
h	g	Lip region not expanded.
j	k	Oesophagus cylindrical or slightly enlarged posteriorly, not distinctly divided into two portions .... *Axonchium.*
k	j	Oesophagus distinctly larger posteriorly than anteriorly.............. *Dorylaimus.*

Spear-bearing Genera at Present Known in Hawaii

Endoparasitic Genera:

(1) Heterodera
(2) Tylenchus
(3) Aphelenchus
(4) Isonchus
(5) Dolichodorus
(6) Hoplolaimus

Exoparasitic Genera:

(7) Axonchium
(8) Dorylaimus
(9) Discolaimus
(10) Ziphinema

Of the spear-bearing nematodes present in the Islands, a certain number are "endoparasitic," i. e., they actually inhabit the internal root structures and are enclosed by them; the others are "exoparasitic," i. e., they live external to the plant itself, but derive nourishment from its internal structures by means of the introduction of a hollow spear through which the vital fluids are sucked.

The genera most commonly met with and which are most destructive in their results are the genus *Heterodera* and the genus *Tylenchus.*

1. *Heterodera:* This genus presents two species:

(a) *Heterodera radicicola.*
(b) *Heterodera schachtii.*

Both species are frequent in their occurrence and produce root lesions of a very characteristic type.

Heterodera radicicola: For a number of years *Heterodera radicicola* has been recognized in these Islands as a sugar cane parasite and was first placed on record by Dr. N. A. Cobb in 1909.

This nematode is very prevalent, widely distributed, and is an "endoparasite" of some virulence. The taxonomic characters are of interest as this species bears a close resemblance to *Heterodera schachtii* and to several of the *Tylenchus* group.

This nematode is unusual in that it produces a characteristic gall formation in the root substance. These form irregularly rounded swellings of variable size, readily visible to the observer and usually situated at the root terminations.

Heterodera schachtii: This species does not give rise to a genuine gall formation. Instead, there is a more uniform thickening of the entire root structure usually some little distance above the peripheral terminations. Associated with this is a marked proliferation and massing together of the collaterals. These also may show an individual spindlar enlargement depending upon the age and degree of the infestation. It is worthy of mention that in sugar cane and in pineapples

the gravid females of *Heterodera schachtii* are actually "endoparasitic" and not merely external parasites, as has been demonstrated in the usual infestation of beet root, etc. Only one other instance of this is on record, viz., a case of beet infection in Algiers when the *Heterodera schachtii* was found as an internal parasite.

2. *Tylenchus:* Of the genus *Tylenchus,* the species (a) *Tylenchus similis* is by far our greatest enemy both in the numbers present and in the extreme seriousness of the effects produced. *Tylenchus similis* is a true parasite inhabiting the internal root structures both cortex and stele, if it so desires.

These nematodes appear to prefer young and healthy root systems, the infestation usually reaching its maximum in cane between 4 to 10 months of age.

By means of its spear, the nematode punctures the external root coverings, enters the cortex and embeds itself in the cellular structures. Its point of ingress is marked by a slight red discoloration and as the infection proceeds, this deepens in intensity and increases in area, eventually giving rise to the dark reddish wine-colored lesions characteristically associated with the diseased conditions produced by *Tylenchus.*

At least three other species of *Tylenchus* have now been recognized infesting our cane roots. Of these (b) *Tylenchus Olaae* was described by Cobb in 1909, but as yet no adequate description has been found for the other two which have been temporarily designated the spiral *Tylenchus* and the small *Tylenchus.*

(c) *Tylenchus (spiral):* This is a nematode of some size, prevalent both in cane and pineapple roots. This nematode possesses the characteristics typical of the *Tylenchus* group and assumes a curious curved attitude peculiar to no other nematode which has come under our observation. The root lesions are similar to those of *Tylenchus similis.*

(d) *Tylenchus (small):* A small species of the genus *Tylenchus* and found inhabiting the roots of the sugar cane usually near the tips. This species is less prevalent than others of the same genus, but it has been demonstrated in several localities and gives rise to reddish discoloration and puncture lesions resembling those of *Tylenchus similis.*

3. *Aphelenchus:* A genus of spear-bearing "endoparasites" closely resembling the *Tylenchus group.* The spear is smaller than in *Tylenchus* and there is no posterior oesophageal bulb. This genus is widely distributed and is usually found together with *Tylenchus similis,* deeply embedded in the root substance some little distance above the tip.

4. *Isonchus:* Another genus closely resembling *Tylenchus* but possessing a spear devoid of basal bulbs. This genus is found in sugar cane and pineapples, and is usually in intimate association with *Tylenchus similis.*

5. *Dolichodorus:* A spear-bearing genus bearing a close resemblance to the *Tylenchus* group. This genus has been found in the sugar cane in Hawaii, but as yet has not been demonstrated in the cane of the other Islands.

6. *Hoplolaimus:* An "endoparasite" of small size and possessing very characteristic transverse striations and a powerful spear. This genus is widely distributed throughout the Islands and is most frequently found in soil in the immediate vicinity of the roots. On several occasions, members of this genus have been

found inhabiting an otherwise actively functioning root and must therefore be considered as true "endoparasites."

The "exoparasitic" nematodes though of somewhat less importance are yet worthy of consideration. They include a number of genera and occasion a fair proportion of plant disease. The method of attack is somewhat different in the case of the "exoparasite." In this instance, the nematode remains external to the plant, introducing only the sharply pointed hollow spear which penetrates the root cortex and by means of which the plant juices are extracted.

Regardless of the harm due to the lesion, its potential significance cannot be forgotten as it affords an open door for all organismal entrance, suitable environment for proliferation and favorable conditions for the production of disease.

Of the genera present in these Islands and attacking the sugar cane, the genus *Axonchium* is perhaps that most frequently met with.

7. *Axonchium:* This genus includes several species and is found universally distributed throughout the Islands. Occasionally members of this genus may be found actually inhabiting the internal root structures, but, owing to the invariable accompaniment of some degree of root decay, this infestation is believed to be accidental and therefore this genus is regarded as a true "exoparasite."

8. *Dorylaimus:* A genus closely resembling *Axonchium* and widely distributed throughout the Islands. This genus includes a number of different species and gives rise to the generalized lesions usually ascribed to *Axonchium*, etc.

9. *Discolaimus:* Another genus closely allied to *Axonchium* and *Dorylaimus*. It gives rise to lesions similar to those produced by the former and is distinguished from them by structural characters.

10. *Ziphinema:* Another genus of the "exoparasitic" group found widely distributed throughout the Islands. The injuries to the root system resemble those of *Axonchium* and others. This nematode is outstanding by reason of the exceptional length of its relatively slender trilobed spear. It has been demonstrated around the roots of cane and various other plants on Oahu and on Maui, but its relative scarcity makes it of minor economic importance.

Potash at Honokaa

[We give herewith data supplied us by the Honokaa Sugar Company and Pacific Sugar Mill on the results of one of their plant food experiments. These results show clear-cut gains for potash. On studying the plot yields one will note that, with but one exception, the plots getting potash gave juices with a better quality ratio than adjoining plots getting nitrogen only. The average quality ratio of the potash plots was 12.01, while that of the nitrogen only plots was 12.65.

Results of the same nature were reported from Ewa Plantation Company in a number of their potash experiments. We did not get this difference in our earlier potash tests, mainly along the Hilo coast.

This may have been due, in part at least, to the fact that in these earlier experiments we did not use as much potash as is now the case. In these earlier tests we generally used from 60 to 125 pounds of K_2O, as compared to amounts of from 200 to 400 pounds now being tried.—J. A. V.]

HONOKAA SUGAR COMPANY AND PACIFIC SUGAR MILL

Fertilizer Experiment No. 27, H. S. Co. Field No. 22 at 1,000 Ft. Elevation, Unirrigated Field. Crop 1926 Short Ratoons—16 Months Old When Harvested.

Summary of Results—Harvested August 31, 1926

Treatments		Tons per Acre			
Pounds per Acre	Q. R.	Cane	Sugar	Gain	Loss
200 Nitrogen and 4000 Mill Ashes	13.23	47.88	3.62	.94	
200 Nitrogen	15.01	40.24	2.68		
200 Nitrogen and 200 P_2O_5	11.34	34.02	3.00	.17	
200 Nitrogen	13.41	38.00	2.83		
200 Nitrogen and 200 K_2O	14.25	44.19	3.10	.32	
200 Nitrogen	14.18	39.40	2.78		
200 Nitrogen, 200 P_2O_5 and 200 K_2O	11.99	39.01	3.25	.67	
200 Nitrogen	12.44	32.15	2.58		
200 Nitrogen, 200 P_2O_5 and 4000 Mill Ashes	9.77	37.92	3.88	.83	
200 Nitrogen	11.78	35.92	3.05		
200 Nitrogen and 8000 Mill Ashes	12.90	41.77	3.24	.56	
200 Nitrogen	13.29	35.64	2.68		
200 Nitrogen and 300 P_2O_5	13.68	36.85	2.69		.29
200 Nitrogen	12.32	36.69	2.98		
200 Nitrogen and 300 K_2O	12.54	42.23	3.37	.61	
200 Nitrogen	14.28	39.40	2.76		
200 Nitrogen, 300 P_2O_5 and 300 K_2O	12.22	48.99	4.01	.52	
200 Nitrogen	10.94	38.14	3.49		
200 Nitrogen, 300 P_2O_5 and 8000 Mill Ashes	10.74	37.75	3.51	.32	
200 Nitrogen	10.83	34.58	3.19		
200 Nitrogen, 400 P_2O_5 and 400 K_2O	10.44	49.47	4.74	.75	
200 Nitrogen	11.09	44.22	3.99		

In this field the cane of the previous crop showed much distress. Symptoms indicating the lack of potash were very pronounced throughout the field, and particularly in the lower lying areas. The figures as shown in the above results fully explain the trouble.

We note that phosphate at the rate of 200 pounds P_2O_5 per acre gives a small gain and 300 pounds P_2O_5 per acre an actual loss. This may be due to an unbalanced plant food when phosphate fails to play its role in the absence of a liberal amount of potash.

E. E. NAQUIN.

Methylene Blue Method for Glucose Determination

By W. R. McAllep

Volumetric glucose methods have been only moderately accurate because of the somewhat indefinite end point and inaccuracies due to the time required to filter off a portion of the solution for making the end point test. The methylene blue modification was proposed and worked out by Lane and Enyon* to remedy these defects. In this method, shortly before the end point is reached a few drops of methylene blue are added to the boiling solution giving it an intense blue color. When the last trace of copper is reduced the blue color disappears thus giving a very sharp end point.

This method has been used extensively at this Station for juice analysis. The results are more consistent than are ordinarily secured with gravimetric methods and much less time is required. We have not yet tried the method out thoroughly on molasses. The end point in molasses analysis is somewhat obscured by the color of the solution, but from what work has been done we believe that with practice the end point can be determined even in dark molasses solutions with a satisfactory degree of accuracy. The following directions are based on Mr. Cook's and Mr. Bomonti's experience with this method.

Solutions

1. Methylene Blue. Dissolve one gram of methylene blue and make up to 100 c.c. with water. Lane and Enyon state that they have not found much difference in samples of methylene blue from different sources. We have found some preparations sold as methylene blue unsatisfactory. The grade of methylene blue used for biological stains is suitable. We have found methylene blue U. S. P. medicinal, Schultz No. 659, put out by the National Analine and Chemical Company satisfactory.

2. Soxhlet's Solution. Prepare Soxhlet's solution as directed on page 21 of Methods of Chemical Control, 1923. This solution should be standardized and adjusted to exact strength as directed below.

3. Standard Invert Sugar Solution. The following solution proposed by Lane and Enyon is recommended: Weigh out exactly 9.5 grams of the purest refined sugar obtainable, add 5 c.c. of concentrated hydrochloric acid and make up to a volume of about 100 c.c. Allow to stand for two or three days if the temperature is as high as 20-25° C. or for a week if the temperature is as low as 12-15° C., then without neutralizing make up to one liter and keep in a well stoppered bottle. This solution is sufficiently acid to prevent the development of micro-organisms and will keep for considerable time. One hundred c.c. of this solution contains one gram of invert sugar.

* Journal Society of Chem. Industry, 1923, pages 34T, 143T and 463T.

Standardization of Soxhlet's Solution

Take 50 c.c. of the invert sugar solution, prepared as above, in a 250 c.c. flask. Neutralize and make up to 250 c.c. with water. Titrate as described below under "Analysis." 25.64 c.c. of the solution should be required. Adjust the copper sulphate solution if necessary (Solution A) until it is of the proper strength. The alkali solution (Solution B) need not be adjusted if it is made strictly according to directions.

Preparing Samples for Analysis

The sucrose content of the sample must be known for this value is used in calculating the results. For ordinary tests on juices the difference between sucrose and polarization may be neglected. Directions given under "Preparation of Samples" on page 40, 1923, Methods, may be followed, except that the amount of sample and the dilution must be varied to suit the requirements of this test. The sucrose concentration in the sample prepared for analysis should not exceed 5 grams per 100 c.c. for this is the highest sucrose concentration in the accompanying table of factors. Preferably the glucose concentration should be such that 25-40 c.c. of the solution, corresponding to 125 to 200 milligrams of glucose per 100 c.c. is required for the titration.

If the approximate glucose content is unknown a preliminary titration should be made. Suitable quantities for a preliminary titration, usually approximating the above specifications are:

Juices, 50 c.c of original juice in 200 c.c. of prepared solution.

Final molasses, 2 grams in 200 c.c. of prepared solution, 10 grams of molasses clarified with neutral lead acetate, made up to 250 c.c. filtered and 50 c.c. of this filtrate deleaded with di-sodium phosphate and made up to 200 c.c. gives the above concentration.

Apparatus

An accurately graduated burette should be used for measuring out the copper solution (Solution A). A calibrated 5 c.c. pipette is sufficiently accurate for measuring out the alkali solution (Solution B). An accurately graduated burette should be used for delivering the prepared sugar solution. The test should be made in an Erlenmeyer flask. A 300 c.c. pyrex glass flask is recommended. A small electric hot plate is a more convenient source of heat than a burner. It is advisable to cover the burner or hot plate with a piece of asbestos board in which a hole approximately the size of the bottom of the flask has been cut to protect the hands. If a flame is used the flask should rest on a wire gauze. A light wire test tube holder, which may be left attached to the neck of the flask, is convenient. A two-minute sand glass is very convenient for timing the boiling.

Analysis

First make a preliminary titration to determine the approximate amount of sugar solution required to reduce all the copper, following in general the directions given below. In the preliminary test add a considerable proportion of the sugar solution before boiling and do not add the methylene blue until near the end point.

Deliver exactly 5 c.c. of the standardized copper solution into the Erlenmeyer flask, add 5 c.c. of the alkali solution. Water must not be added, for dilution will give erroneous results. Then add to within 1 c.c. of the amount of sugar solution required to completely reduce the copper. Bring to boiling and boil for exactly two minutes. Add five drops of the methylene blue solution preferably with a medicine dropper. Without removing the flask from the heat or interrupting the boiling, add the sugar solution cautiously from the burette, held in the hand, until the end point is reached, taking not over one minute to complete the titration. The total time of boiling must be three minutes. After each addition of sugar solution the flask should be given a rotary motion without removing it from the flame or stopping the boiling. The solution should be kept boiling rather vigorously throughout the test to keep the flask as free from air as possible. A very slight contact with air will reoxidize the methylene blue and give erroneous results.

End Point

The end point is very sharp but as it is somewhat obscured by the reduced copper in the boiling solution it is sometimes difficult at first to detect it with certainty.

When the methylene blue is added it colors the contents of the flask a deep blue. The color persists with but little change until all but a very small amount of the copper has been reduced, when it begins to fade. As the blue fades the yellow color of most sugar solutions will give the solution a greenish tint. A green color indicates a very close approach to the end point and two or three drops more are usually sufficient to complete the titration.

The color of the liquid can usually be seen best at the edge of the solution. While learning to judge the end point the flask may be removed for an instant. When the copper begins to settle the color of the solution can be seen clearly. This is a dangerous practice and is not recommended for regular work, for as soon as boiling stops, air is liable to enter the flask and reoxidize the methylene blue. However, it is possible to stop the boiling for an instant without seriously interrupting the flow of steam from the flask.

As the blue color fades the color of the reduced copper appears brighter and after the blue color is discharged does not change further. This appearance can be recognized. After experience has been gained, the greenish tint denoting the close approach to the end point, the disappearance of the green tint particularly at the edges of the solution and the characteristic appearance of the copper precipitate enables the exact end point to be located with little if any uncertainty.

The end point of this test is so sharp that at least in juices, the accuracy with which solutions are made up and measured out, and how closely the directions for conducting the test are followed will usually be the limiting factors in the accuracy of the results rather than detecting the exact end point.

Excessive frothing interferes with detecting the end point and increases the danger of back oxidation. When solutions froth excessively rub a very small amount of vaseline inside the neck of the flask. On melting this will run down and reduce the frothing sufficiently so that the end point is not obscured. This does not affect the results.

Calculation of Results

Look up the factor corresponding to the c.c. of sugar solution used, in the column corresponding to the sucrose concentration of the prepared solution, interpolating between columns if necessary. Dividing this factor by the c.c. of sugar solution used and multiplying by a hundred gives the glucose, calculated as invert sugar, in the solution prepared for analysis in mg. per 100 c.c. From the weight of the original sample in 100 c.c. of the prepared solution and the milligrams of invert sugar per 100 c.c. calculate the per cent of glucose in the original sample.

Example: The juice is 12 Brix and 10 per cent sucrose. In preparing this sample for analysis the dilution is such that 100 c.c. of the prepared solution contains 25 c.c of the original sample. The sucrose concentration of the prepared solution is therefore 2.5 grams per 100 c.c. On titration it is found that 30.0 c.c. of the solution is required.

Interpolating between the 2 and 3 gram columns we find the factor is 49.4.

$$\frac{49.4 \times 100}{30} = 164.7 \text{ milligrams glucose per 100 c.c. of prepared solution.}$$

100 c.c. of the prepared solution contains 25 $\times$ 1.10505 (the specific gravity corresponding to 12.0 Brix) = 27.63 grams of the original sample.

$$\frac{.1647 \times 100}{27.63} = 0.596 \text{ per cent glucose.}$$

FACTORS: METHYLENE BLUE VOLUMETRIC GLUCOSE METHOD

The factor divided by the c.c. of sugar solution used × 100 gives milligrams of glucose per 100 c.c. when 5 c.c. each of Soxhlet's Solutions A & B are used

C.C. Sugar	Sucrose per 100 c.c. of Sugar Solution						
Solution	0	.5 Gram	1 Gram	2 Grams	3 Grams	4 Grams	5 Grams
15	50.5	50.2	49.9	49.4	48.8	48.3	47.6
16	50.6	50.3	50.0	49.4	48.8	48.3	47.6
17	50.7	50.4	50.1	49.4	48.8	48.3	47.6
18	50.8	50.4	50.1	49.4	48.8	48.3	47.6
19	50.8	50.4	50.2	49.5	48.9	48.3	47.6
20	50.9	50.5	50.2	49.5	48.9	48.3	47.6
21	51.0	50.6	50.2	49.5	48.9	48.3	47.6
22	51.0	50.6	50.3	49.5	48.9	48.4	47.6
23	51.1	50.7	50.3	49.6	49.0	48.4	47.6
24	51.2	50.7	50.3	49.6	49.0	48.4	47.6
25	51.2	50.8	50.4	49.6	49.0	48.4	47.6
26	51.3	50.8	50.4	49.6	49.0	48.4	47.6
27	51.4	50.9	50.4	49.6	49.0	48.4	47.6
28	51.4	50.9	50.5	49.7	49.1	48.4	47.7
29	51.5	51.0	50.5	49.7	49.1	48.4	47.7
30	51.5	51.0	50.5	49.7	49.1	48.4	47.7
31	51.6	51.1	50.6	49.8	49.2	48.5	47.7
32	51.6	51.1	50.6	49.8	49.2	48.5	47.7
33	51.7	51.2	50.6	49.8	49.2	48.5	47.7
34	51.7	51.2	50.6	49.8	49.2	48.5	47.7
35	51.8	51.3	50.7	49.9	49.2	48.5	47.7
36	51.8	51.3	50.7	49.9	49.2	48.5	47.7
37	51.9	51.3	50.7	49.9	49.2	48.5	47.7
38	51.9	51.3	50.7	49.9	49.2	48.5	47.7
39	52.0	51.4	50.8	50.0	49.2	48.5	47.7
40	52.0	51.4	50.8	50.0	49.2	48.5	47.7
41	52.1	51.4	50.8	50.0	49.2	48.5	47.7
42	52.1	51.5	50.8	50.0	49.2	48.5	47.7
43	52.2	51.5	50.8	50.0	49.3	48.5	47.7
44	52.2	51.5	50.9	50.0	49.3	48.5	47.7
45	52.3	51.5					
46	52.3	51.5					
47	52.4	51.6					
48	52.4	51.6					
49	52.5	51.7					
50	52.5	51.7					

The History and Distribution of Eye Spot

By H. Atherton Lee

Eye spot is one of the oldest infectious diseases of sugar cane for which there is any authentic record. As early as the year 1892, eye spot was described in Java. A colored illustration and a more complete account of the appearance of the disease in Java were published in 1898 by the two investigators, Wakker and Went (7); this plate, illustrating the nature of the disease, shows it to be identical with eye spot of the Hawaiian Islands.

Apparently the cane varieties grown on a plantation scale in Java have been, with one or two exceptions, resistant to eye spot, and the disease has not been considered important there.

Eye Spot in Other Countries

Eye spot is also widely distributed in many other cane-growing countries. It is known in India, the Philippines, Formosa, Cuba, Porto Rico, Jamaica, Barbados, Trinidad, Santo Domingo and Reunion, as well as Java and the Hawaiian Islands. In these other countries, also, varieties which are resistant to eye spot have been commonly grown and the disease has not been considered serious.

More recently, however, in Porto Rico eye spot is occasionally bad on new seedling varieties which have high susceptibility to the disease (Cook 3). Miss Wilbrink, the cane pathologist of the Java Sugar Experiment Station, stated in conversation that she also observed the disease severely attacking new seedlings in Santo Domingo, and H. P. Agee stated that he observed the disease occurring severely in several areas in Florida. There is one instance of an outbreak in Java; Miss Wilbrink told of an outbreak one year on the variety P. O. J. 100 which was very severe in one district; however, the disease did not recur. It is apparent that with the extension of new seedling varieties, eye spot is receiving more attention than it has in the past in other cane growing countries.

Fire Blight or Top Rot in Early Days in the Hawaiian Islands

In the Hawaiian Islands as early as the year 1854 there was an account of a serious disease called "fire blight," at Lihue, Kauai. The account of this disease was contained in the annual address by the Honorable William L. Lee (5), president of the Royal Hawaiian Agricultural Society, in June, 1854. Extracts of this address are as follows:

> The last year's crop has not equalled our expectations, though it has exceeded that of the year before. We estimate the whole produce of the islands for the last season at 800 tons, which, with the syrup and molasses, is valued at $120,000. The present crop of the Koloa Plantation, on Kauai, owned by Dr. R. W. Wood and Mr. Burbank, will amount

to 300 tons of beautiful sugar, which, at six cents per pound, makes the handsome sum of $36,000. Its syrup and molasses I estimate at ten thousand dollars more, which shows a total of $46,000. The whole expenses of the plantation per annum do not exceed, I am told, fifteen thousand dollars. Comment is unnecessary.

The Lihue Plantation, owned by Henry A. Pierce & Company, only ten miles distant from that of Koloa, has been less favored. Owing to causes which no human agency could avert, the large crop anticipated has proved an almost complete failure. A year ago last December the prospects at Lihue were cheering in the highest degree, and we were sure that we should harvest a crop this season of at least 400 tons. The sun never shone on finer fields of cane. In January a storm came, accompanied with terrible thunder and lighting, and blasted our smiling fields as with the breath of fire. After the storm passed, the cane fields grew brown, rotted and died, and 400 acres that should have brought us at least $50,000, hardly produced one-sixth part of that sum.

The whole crop did not exceed fifty tons. The cause of this fire blight is still a mystery. At first we thought that it might be the work of an insect, but the closest examination showed that we were mistaken, and we can ascribe it to nothing but some great convulsion in the atmosphere.

The account of this "fire blight" answers in many ways to a description of eye spot. The fields were green in December, but following rains in January the fields became brown. The disease did not occur at Koloa with its southern exposure, but at Lihue with its eastern exposure and ridges of hills shutting off sunlight and air movement the disease broke out. This is similar to eye spot occurrences at the present time. It is shown by the previous annual report of the Royal Hawaiian Agricultural Society that a small lot of "Tahiti" cane had just been introduced at Lihue, and it seems probable that this was another introduction of the cane which subsequently became known as Lahaina. In this case it would seem that Lahaina cane had not been widely planted at Lihue in 1854, which would mean that some of the native varieties were being grown then on a plantation scale at Lihue. L. D. Larsen, manager of Kilauea Sugar Plantation Company, and formerly pathologist at the Experiment Station, concurs in this view and states that in previous years, working on eye spot, he found that several of the native canes were extremely susceptible.

Of the infectious diseases which occur in these Islands at the present time, the account of this fire blight in 1854, is most descriptive of eye spot.

In the early days at Waialua, W. W. Goodale, in conversation, states that eye spot was called top rot. The disease was known there at a very early date and in 1904 or 1905, several fields growing the Lahaina variety were so severely attacked that the cane was plowed out and the fields planted in other crops.

Lewton-Brain (6), of this Experiment Station, in first describing eye spot as a known infectious disease of these Islands, in 1907, mentioned that the disease had been previously called rust. It seems very probable, therefore, that eye spot has existed in the Hawaiian Islands for many years although the well established records of the disease under the name "eye spot" only date to 1907.

Investigations on the Cause of Eye Spot

The fungus causing eye spot was first described by the Dutch investigator Van Breda de Haan (1) in the year 1892; he described the fungus as *Cercospora*

sacchari. He also tried infection tests and was able to reproduce the disease by inoculation of the leaf blades of sugar cane with the spores of this fungus, thus establishing the causal relationship of the fungus to the disease.

Mr. Larsen (4), in 1912, isolated the same fungus in pure cultures, from the disease in the Hawaiian Islands, and was able to reproduce eye spot on cane plants by spraying the leaves with an infusion of the spores from such cultures. This confirmed the work of Van Breda de Haan in Java.

In India the causal fungus was described in the year 1913 by the English investigator, Butler (2), independently of the Java workers; Butler placed the fungus in the genus *Helminthosporium* and called it *Helminthosporium sacchari,* instead of *Cercospora sacchari.* The nomenclature of Butler is usually followed by investigators at the present time. Butler also carried on infection tests and reproduced the disease with the eye spot spores, so that it is established beyond question that the agent causing eye spot is the fungus *Helminthosporium* (*Cercospora*) *sacchari.* At the present time, given proper atmospheric moisture we are able to reproduce eye spot at will by spraying plants with infusions of the eye spot fungus.

The Present Outbreak of Eye Spot in These Islands

During the past twenty years, the varieties widely grown in these Islands have not been highly susceptible to eye spot; Rose Bamboo, Yellow Caledonia, Striped Mexican, D 1135, Badila and the Tip canes are all very highly resistant to this disease; Lahaina has been much less susceptible than H 109.

In 1910, in *The Hawaiian Planters' Record* is a statement concerning eye spot and ring spot as follows: "There is little possibility that in our climate they will be able to kill the cane outright. The great danger from these diseases is that, attacking the cane as they do when the weather conditions are unfavorable to its growth, they may so reduce its vitality that some aggressive fungus will be able to carry it off."

However, eye spot has been creating increasing attention since then.

In 1911, Mr. Larsen stated: "On two of the plantations (on Oahu) eye spot was found to be quite severe. . . . " In the same year, in an editorial in *The Planters' Record,* it was stated: "Eye spot (on Maui) was found wherever Lahaina cane was grown and was reported as a disease of no inconsiderable importance. It was said to be most severe during the months of February and March, and to disappear entirely with the warm weather in May and June. As a general rule it was found to be more severe on new land than in fields which had been under cultivation for any length of time."

It is only with the extensive spreading of H 109, with its high susceptibility to this one particular disease, that eye spot has become an important factor in plantation practice in some localities in these Islands. The increase in eye spot infection in these areas has, moreover, been cumulative with the spread of H 109, for with the increase in H 109 there have consequently been greater sources for infection and spread of the disease. The increase in eye spot in certain localities seems to be, therefore, not due to an increase in virulence of the fungus so much

as to the great spread of a susceptible cane variety and a corresponding great increase of sources of infective material, i. e., eye spot spores.

This brief history brings the subject to the present time, when efforts are being made to combat eye spot in these Islands by obtaining resistant varieties equally as productive as H 109 for the affected areas, or, without sacrificing H 109, by field practices to minimize or prevent eye spot.

Summary

(1) A disease called "fire blight" did much damage to cane in the Hawaiian Islands as early as the year 1854, and the description of "fire blight" agrees in many ways with the appearance of eye spot.

(2) The first well established record of eye spot was in 1892 in Java; the first well established record in the Hawaiian Islands was in 1907.

(3) Eye spot is widely distributed in many countries and occurs in India, the Philippines, Formosa, Cuba, Porto Rico, Jamaica, Barbados, Trinidad, Santo Domingo and Reunion, as well as Java and the Hawaiian Islands.

(4) A fungus as the cause of eye spot was first established in Java in the year 1892, and the fungus was called *Cercospora sacchari* by the Dutch investigator Van Breda de Haan. Larsen, in the Hawaiian Islands, confirmed the work of Van Breda de Haan, establishing a fungus as the cause of eye spot. Butler in India, independently of these other workers, established the same fungus as the cause of eye spot, but placed its systematic position differently, placing it in the genus *Helminthosporium* as *H. sacchari*. The nomenclature *Helminthosporium* (*Cercospora*) *sacchari* Butler is now in general usage by investigators.

(5) Only in the last few years has eye spot become an important factor to be contended with in cane growing in the Hawaiian Islands. This is due to the extensive planting of the susceptible variety H 109 in situations favorable for eye spot development. The spread of H 109 in such situations favorable for eye spot has not only meant more eye spot, but more sources of infection for the spread of the disease.

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Description of Eye Spot as Compared With Other Sugar Cane Leaf Spot Diseases

By H. Atherton Lee and J. P. Martin

During the past few seasons reports of the occurrence of eye spot have sometimes been received, and on investigation it has been found that other less serious diseases have been confused with eye spot. The following is a brief description which may aid in distinguishing eye spot from other diseases.

Standard Varieties Affected

The varieties affected serve to aid in distinguishing eye spot from other diseases. Yellow Caledonia, Badila, Striped Mexican and Uba are so seldom affected that one can usually be sure that large spots and reddish streaks found on these varieties are not eye spot. When these varieties occur in the midst of a field of a susceptible variety, they will sometimes be infected, but the spots produced are so small that they usually will not be noticed and there will be no red streaks spreading from the original infections.

D 1135 and the Tip canes are seldom affected, but when planted adjacent to a susceptible variety they occasionally become infected. The spots produced on these varieties are usually of a good size and readily noticeable, and in appearance are similar to early infections on H 109 or Lahaina.

On all varieties eye spot affects the younger leaves. The other leaf spot which is usually confused with eye spot is ring spot. Whereas, eye spot affects the younger leaves, ring spot is found only on the older leaves; this alone is an easy way to aid in distinguishing eye spot from other leaf spots in the Hawaiian Islands.

Of the standard varieties grown in the Hawaiian Islands, H 109 and Lahaina are the most commonly affected. Reddish spots on the younger leaves of these two varieties, which extend into long yellow or reddish streaks, are almost certainly eye spot infections. A more detailed description of eye spot follows:

Detailed Description of Eye Spot in the Variety H 109

The first indications of the development of a lesion are noticed when a small oblong spot shows on the leaf, of a watery, darker green than the normal leaf, and from one-eighth to one-fourth inch long and one-sixteenth inch or thereabouts in width. This stage shows up immediately after infection of the leaf by

Ring Spot

Eye Spot

the fungus, and may appear on either upper or lower surfaces of the leaf; it will rarely be noticed in the fields under usual plantation conditions.

After three or four days, such a dark green area becomes a pale yellow, straw-colored oval lesion, visible on both upper and lower surfaces of the leaf, one-fourth inch to three-eighths inch in length. This yellow area gradually enlarges and after seven or eight days reddish-brown oval spots appear in the center of the yellow spots; the yellow areas make a sort of halo-like appearance about each red spot. The longest axis of the spots is in the direction of the length of the leaf. The yellow halo then begins to elongate into a streak running upwards on the leaf; this streak is at first yellow but then becomes a reddish-brown. Occasionally streaks may extend downward on the leaf for a short distance, but the majority of streaks run upward; they may be from one-eighth to three-eighths inch in width. Such streaks sometimes reach a length of 18 to 36 inches. Where very many eye spot lesions occur on the same leaf, these streaks coalesce and cause the whole leaf to become a reddish-brown color and the leaves die back from the tips and edges; where this condition becomes general on many plants the field as a whole assumes a reddish-brown appearance, for which the name "fire blight," used in the old days, was very appropriate.

The original oval spot, which became visible before the streak formed, often dies in the center and there is then a slender oval dead area of leaf which is a pale brown or ashen color, inside of the red ring. The yellow halo surrounding the red spot has often disappeared at this stage.

Where a leaf becomes badly infected and many long reddish streaks are formed, the young, newly formed leaves in the central cylinder also often become badly infected and the infection runs down into the top of the cane and a top rot results. Such a top rot is the worst effect of eye spot. The leaf blade is principally attacked; the midrib is rarely attacked, if at all, in the case of H 109, and the leaf sheath also is rarely attacked. Occasionally, in severe cases, the cane stalk itself is attacked and such lesions on the stalk appear to permit the ingress of other stalk-rotting organisms and they cause severe injury.

In the Hawaiian Islands there are but two diseases, ring spot, mentioned previously, and red stripe, which could readily be confused with eye spot. Eye spot and ring spot have readily obvious differences. Eye spot is more reddish in color than ring spot, which is brown. Ring spot never runs into a long narrow streak as does eye spot. As mentioned previously, also, eye spot attacks the younger leaves, whereas ring spot attacks the older outside leaves. These differences are shown much more clearly in the accompanying colored illustration by Potter than is possible to bring out in a written description.

Red stripe disease results in a long streak of a dark purplish-red color and has very even regular edges. The reddish streaks of eye spot are lighter colored and more brownish than those of bacterial red stripe. Eye spot streaks, moreover, have very irregular indefinite edges often with yellow areas along the edges not seen in red stripe disease. Red stripe does not affect Lahaina or H 109 and is very common on the Tip canes, whereas, as mentioned previously, eye spot rarely attacks the Tip canes, but is very common on Lahaina and H 109 varieties.

Losses Caused by Eye Spot

By H. Atherton Lee

Different Types of Injury

When but one or two eye spot lesions occur to a leaf in a cane field, the injury to the cane is scarcely noticeable. However, often the leaves may show 20 or 30 eye spots, and such a large number causes the leaf to become entirely brown and of no value in functioning for the plant. This type of leaf injury shows, a few months later, in the cane stick, which will be much reduced in diameter and the joints much reduced in length. In such cases of heavy leaf infection there is also a slightly deleterious effect upon the juices of the cane.

The worst injury from eye spot, however, results from top rot, which is brought about by very heavy infection of the young new leaves in the central cylinder or spindle of the cane top. When these very young leaves become heavily infected the killed area often extends down into the growing bud of the cane and top rot results.

After such top rot the cane may produce lalas, but very often secondary fungi follow the top rot and invade the sound stalk below the top, resulting in total loss of the cane stick.

Most eye spot areas do not reach the top rot stage. The field areas with heavy leaf infection are more widespread than those with the top rot stage, and the mildest degree of infection where but a single spot or two occurs per leaf is much more widespread and can be found on most plantations, causing, however, little or no loss.

Effect on the Cane Juices

Some figures on the deterioration in juices following top rot from eye spot are as follows. These data have been furnished by Mr. Larsen, manager of Kilauea Plantation, and are the most comprehensive to date, being in carload lots:

						Juices					
	Car No.	No. of Cane Sticks	Per Cent of Total	Total Weight Net	Weight per Stick	Brix	Pol	Pur	Q. R.	Total Sugar	Sugar per Stick
Healthy	98			2418							
	204			2473							
		1230	54.42	4891	3.977	20.79	18.79	90.4	7.0	698.8	.5682
Tops dead from eye spot	294	400	17.80	848	2.12	16.19	12.16	75.1	12.56	67.52	.1688

In the above test Mr. Larsen had the cane brought in from the field in the cars, with the tops on. At the factory, he personally separated healthy sticks from sticks with top rot following eye spot. There was a third class which he

separated, the tasseled sticks, but these are not reported in the above table since Mr. Larsen will present the tasseling results in person.

A similar test from another field affected with eye spot gave the results tabulated by Mr. Larsen as follows:

Class	No. of Cane Sticks	Per Cent of Total	Total Weight Pounds	Weight per Stick	Juices Brix	Juices Pol.	Juices Pur.	Juices Q. R.	Total Sugar Pounds	Sugar per Stick Pounds
Healthy	400	33.32	1776	4.44	19.92	17.98	90.2	7.4	240	.60
Dead or partly dead from eye spot	200	16.67	591	2.95	17.02	14.53	85.3	9.4	63	.31

We have other data which agree with the above, showing that cane affected with top rot following eye spot has much poorer juice qualities than unaffected cane, as well as lessened weight.

Acreage Affected and Losses Incurred in the 1926 and 1927 Crops

Eye spot is usually most severe on the first season's growth and does not usually affect mature cane severely; it is, therefore, possible to present the figures for the acreage of H 109 affected in the 1927 crop as well as the 1926 crop.

In the following table is a compilation of the acreage of H 109 affected with eye spot, and estimates of the losses incurred throughout the Islands. The figures for the acreage affected are fairly accurate but the figures for the losses incurred have a value only as estimates. It is, nevertheless, obvious that a good estimate of losses is much more definite than no figure whatsoever. Both the acreage involved and the estimates of losses have been worked out in close cooperation with the plantation skilled staffs so that they represent the plantation views as well as our own.

EYE SPOT LOSSES BY ISLANDS—1926 CROP

Island	Acreage of H 109	Acres With Eye Spot Injury	Percentage of H 109 Acreage	Acreage of All Varieties	Percentage of Total Acreage	Estimated Losses Tons Sugar	Percentage Loss on Crop
Oahu	20,615	880	4.2	23,522	3.7	613	0.28
Kauai	10,438	650	6.2	22,276	2.5	485	0.37
Maui	14,550	0	0.0	20,001	0.0	0	0.00
Hawaii	580	0	0.0	52,483	0.0	0	0.00
Totals	46,183	1,530	3.3	118,282	1.3	1,098	0.14

Total 1926 crop estimated at 772,000 tons (figures from A. M. Nowell, Manager of Sugar Factors Company, Ltd.).

EYE SPOT LOSSES BY ISLANDS—1927 CROP

Oahu	18,645	849	4.5	21,094	4.0	612
Kauai	10,227	1,173	11.4	23,516	4.9	846
Maui	16,277	0	0.0	20,077	0.0	0
Hawaii	602	0	0.0	51,775	0.0	0
Totals	45,751	2,022	4.4	116,462	1.7	1,458

In the foregoing tabulations, the acreages of H 109 are taken from the 1926 Acreage Census (Experiment Station, H. S. P. A., Circular 46, by J. A. Verret). When the acreages of the 1926 crop are tabulated it is seen that only 3.3 per cent of the H 109 acreage was affected with eye spot, leaving 96.7 per cent of the H 109 acreage which was not injured. Of the total acreage of all varieties, 98.7 per cent is free from injury due to eye spot. In the 1927 crop, 4.4 per cent of the H 109 acreage was affected, showing that there was an increase of the disease.

Although the compilations (the estimates for the 1926 crop, 772,000 tons, were obtained from A. M. Nowell, manager of Sugar Factors Company) show a loss in yields of the 1926 crop to the industry as a whole of only 14/100ths of one per cent, it does not entirely represent the situation. The 1927 crop had considerably increased acreage affected, even under the conditions of last winter, which were considered adverse for eye spot. If the coming winter is favorable for eye spot our losses will be very much greater, due to the large sources for the spread of infection which are being carried over this summer. Moreover, although the industry as a whole does not suffer severely, to those few plantations that are affected eye spot is a matter of vital importance. Still another factor to consider is, that with the large acreages of H 109 there is an increasing amount of eye spot, and consequently larger and more sources of infection for the spread throughout previously unaffected fields and to previously unaffected plantations.

Our feeling is that we are worried about eye spot on a few plantations, but that for the Islands as a whole there is no need for alarm. Nevertheless, there is need for earnest endeavor to cut down these losses and prevent spread of the disease.

The Effect of Drying on the Spores of the Eye Spot Fungus

By J. P. Martin and H. Atherton Lee

Some micro-organisms are readily killed by exposure to dry air; as an example, the bacteria of red stripe disease of sugar cane die out completely in twenty-four hours when exposed in thin infusions to the dry air of a cloudless day at the Experiment Station. In the case of eye spot under field conditions, there is a natural diminution of the disease usually beginning in March and almost completely disappearing in June; knowledge of how the spores of the eye spot fungus endure the dry-air conditions of cane fields after this disappearance of the disease in June, until the following October, enables one to attempt preventive methods more intelligently. The following is an account of experiments in which the resistance was tested of the spores of the eye spot fungus to dry air conditions.

Method

Twenty-five covered culture dishes, each dish containing ten small circular cover glasses, were sterilized. An infusion of the eye spot spores was prepared in sterile water and a drop of such infusion was placed on each cover glass under aseptic conditions. Each drop contained from 20 to 25 spores of the eye spot fungus. The culture dishes containing the cover glasses were then placed in a chamber in which the normal atmospheric conditions of the laboratory existed but where possibilities of contamination from dust were much minimized. At given intervals during the drying period, 5 or 10 of these inoculated cover glasses were removed from the culture dishes and placed, under aseptic conditions, in tubes of liquid culture medium; nutrient bouillon was used for the culture medium. If the fungus spores still lived after the drying, growth of the eye spot fungus occurred in the bouillon tubes, while if the spores were killed by the drying the bouillon tubes showed no growth.

The experiment was repeated and the results of both tests are shown in the following table:

TABLE I

SHOWING GROWTH RESULTING FROM EYE SPOT SPORES AFTER PERIODS OF EXPOSURE TO DRY AIR CONDITIONS

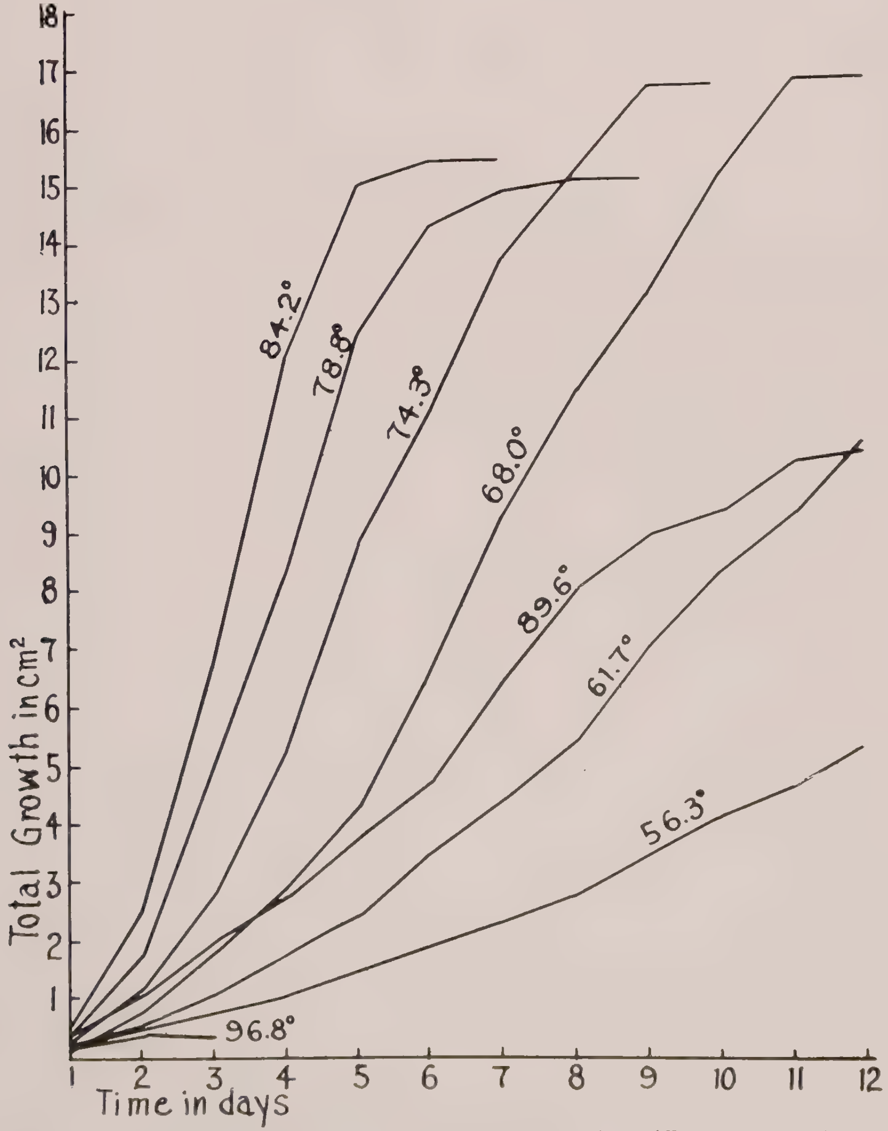
Interval of Exposure to Drying in Hours and Days	Started October 16, 1924 Number of Cover Slips Tested	Started October 16, 1924 Number of Tubes Showing Growth	Started April 18, 1925 Number of Cover Slips Tested	Started April 18, 1925 Number of Tubes Showing Growth
½ Hour	5	5	5	5
1 "	5	5	5	5
5 Hours	5	5	5	5
12 "	5	5	5	5
24 "	5	5	5	5
2 Days	5	5	5	5
3 "	5	5	5	5
4 "	5	5	5	5
5 "	5	5	5	5
6 "	5	5	5	5
7 "	5	5	5	5
8 "	5	5	5	5
10 "	5	5	5	5
12 "	5	5	5	5
15 "	5	5	5	5
18 "	5	5	5	5
20 "	5	5	5	5
25 "	5	5	5	5
30 "	5	5	5	5
40 "	5	5	5	5
50 "	5	4	5	5
60 "	5	5	5	5
70 "	5	5	5	5
80 "	..	..	5	5
82 "	10	4	..	..
85 "	..	..	5	5
90 "	..	..	10	1
95 "	10	1	10	6
100 "	..	..	10	4
105 "	..	..	10	3
106 "	10	0	..	..
110 "	..	..	10	1
115 "	..	..	10	1
120 "	..	..	10	2
127 "	..	..	10	4
133 "	69	0	..	..
140 "	..	..	10	1
145 "	..	..	10	0

These results show that the eye spot spores are very resistant to drying. The conditions of constant atmospheric dryness in the laboratory are probably more adverse to the fungus spores than the conditions which exist in cane fields, where occasional showers and a fairly high humidity exist. There is no question, therefore, but that the eye spot spores can survive in large numbers through the summer from one eye spot season to another.

Relation of Temperatures to the Growth of the Eye Spot Fungus

*A Review of a Paper by F. F. Halma and H. S. Fawcett**

Eye spot is generally considered a cold weather disease. There has been a feeling, however, that the relation of cold weather to the disease is not so much due to more favorable growth of the eye spot fungus at lower temperatures as to



Graph showing the growth of *Helminthosporium sacchari* at different temperatures with time.

* Phytopathology, Vol. 15, No. 8, p. 463, August, 1925.

the presence of moisture for long periods on the cane leaves, from dews, or rains in the colder months, and the lessened hours of sunlight during the winter months when cold weather occurs.

Apparatus and methods have been developed by Dr. H. S. Fawcett, of the University of California, to accurately compare the activities of fungi and other micro-organisms at different fixed temperatures. In order to save the time and expense of duplication of such apparatus, Dr. Fawcett was asked if he would test out the eye spot fungus at different temperatures with his apparatus in California, which he kindly consented to do. Cultures of the eye spot fungus, *Helminthosporium* (*Cercospora*) *sacchari* Butl. were, therefore, sent to Dr. Fawcett, and in the publication mentioned above he and Mr. Halma, his assistant, have recorded these results.

Growth Versus Temperature Experiments

The growth of the fungus was determined on standard nutrient agar, pH 6.8, in glass Petri culture dishes at various temperatures, as noted in Table I. The best average growth from ten such cultures at each temperature determined the optimum for the growth of this fungus.

The accompanying illustration shows the rate of growth of the eye spot fungus at different temperatures with advancing age.

From the illustration it can be seen that at 96.8° F. the fungus was at an entire standstill with practically no growth; the authors showed that the fungus was not killed at this temperature but growth merely stopped. Growth at 89.6° F., was very slow. Growth was most rapid at 84.2° F., but over a period of ten days growth at 68° and 74.3° F. was more extensive. Growth was considerably retarded at temperatures at 61.9° and 56.3° F. This is also shown in the results of the tests recorded in Table I.

TABLE I

Growth of *Helminthosporium sacchari* on Standard Nutrient Agar at Different Temperatures

Days	Temperature in Degrees Fahrenheit							
	56.3	61.9	68.0	74.3	78.8	96.8	89.6	96.8
1	5.1*	4.6	4.8	6.5	7.4	8.6	6.9	5.2
	0.2	0.2	0.2	0.3	0.4	0.6	0.4	0.2
2	7.6	8.6	10.1	12.7	15.4	18.2	12.1	7.2
	0.5	0.6	0.9	1.2	1.9	2.6	1.1	0.4
3	10.1	11.8	15.2	19.1	25.1	29.7	16.0	Growth ceased
	0.8	1.1	1.8	2.8	4.9	6.9	2.0	
4	12.1	15.2	19.2	26.1	32.6	39.2	18.8	
	1.1	1.8	2.9	5.3	8.3	12.1	2.8	
5	14.0	17.5	23.7	33.6	40.1	43.8	21.9	
	1.5	2.4	4.4	8.9	12.6	15.1	3.8	
6	15.7	21.0	29.2	37.8	42.8	44.5	24.6	
	1.9	3.5	6.7	11.2	14.4	15.5	4.8	
7	17.3	23.6	34.6	41.9	43.7	Growth ceased	28.9	
	2.3	4.4	9.4	13.8	14.9		6.5	
8	19.1	26.9	38.2	44.3	44.0		32.3	
	2.8	5.7	11.5	15.3	15.2		8.1	
9	21.1	30.1	41.1	46.3	Growth ceased		33.8	
	3.5	7.1	13.2	16.8			9.0	
10	23.1	32.6	44.2	Growth ceased			34.7	
	4.2	8.3	15.3				9.4	
11	24.5	34.6	46.4				36.3	
	4.7	9.4	16.9				10.3	
12	25.9	36.9	Growth ceased				36.5	
	5.3	10.7					10.4	

* Upper number = diameter of mycelium in mm.; lower number — area of mycelium in cm^2.

The data obtained on solid nutrient culture media were checked by weighing the fungus mycelium grown in liquid culture media at the same temperatures. The results of such tests in bouillon cultures are shown in Table II:

TABLE II

Temperature F. °	Average Weight of Air-Dried Mycelium in mg.	pH of Bouillon at End of 10th Day
56.3	51.0	6.9
61.9	75.0	7.3
68.0	126.0	8.0
74.3	132.5	8.2
78.8	157.0	8.2
96.8	136.5	8.2
89.6	53.5	7.0
96.8	10.0	6.9

The results of these weighings of mycelium grown in nutrient bouillon at the different temperatures are very similar to the results obtained on the solid culture media. In passing, Halma and Fawcett noted that the reaction of the bouillon became decidedly alkaline where vigorous fungus growth took place.

Discussion

When one considers temperatures at or near the sea level in the Hawaiian Islands one is led to the conclusion that ordinary winter temperatures, but not necessarily the extreme minimum temperatures, are more favorable for growth of the eye spot fungus than the summer temperatures. In Honolulu, the mean November temperature is 74.7°; December, 72.8°; January, 70.7°; February, 71.1°; and March 71.3°. These are the temperatures at which the eye spot fungus makes the most extensive growth.

The extreme minimum temperatures in the winter months have been: November, 59°; December, 55°; January, 54°; February, 52°, and March, 53°. These figures are taken from the records of the Honolulu office of the Federal Weather Bureau, U. S. Department of Agriculture, which have been compiled over a period of thirty-four years. These low temperatures only occur rarely and the fungus growth, although retarded at such temperatures, is not inhibited entirely.

On the other hand, mean summer temperatures run as follows: May, 74.8°; June, 76.4°; July, 77.4°; August, 78.2°; September, 78.0°, and October, 76.9°. The extreme maximum temperatures in the summer months are: May, 87°; June, 88°; July, 88°; August, 88°; September, 88°, and October, 90°. These figures are those of air temperatures at a considerable elevation above the ground and in the shade.

In cane fields, conditions are much more favorable for high temperatures than the conditions under which the above temperature figures were obtained. Our recording thermometers in direct sunlight frequently register 20° higher than an identical instrument in the shade, over a period of 6 to 8 hours each day. Where a recording thermometer will register 86° and 88° in the shade, an identical instrument in the direct sunlight near by will often register 108° or 110° F.

Moreover, it has been shown by investigators (Seeley) that green leaves in direct sunlight exceed atmospheric temperatures by as much as 20° or even 36°. Therefore, in summer months, in view of the results by Halma and Fawcett, with periods of 8 to 10 hours of direct sunlight the leaf temperatures would seem to be sufficiently high to inhibit eye spot growth entirely.

In winter months, direct sunlight is for much shorter periods and is also frequently obscured by clouds so that the direct effect of winter temperatures, regardless of the indirect effects of such temperatures in relation to moisture and rain, is more favorable for the development of the eye spot fungus than the summer temperatures.

In the absence of direct sunlight, leaves of plants quickly become colder than the air. In the winter months with longer hours of darkness, this difference may amount to 9° or 10° F. (Seeley), that is, cane leaves may be 9° to 10° cooler than the surrounding atmosphere. This, of course, brings about a condensation of the atmospheric moisture and results in long hours of dew on the leaves in the winter months of lower temperatures and shorter periods of direct sunlight. The indirect effects of winter temperatures, as well as the direct effect, are therefore much more favorable for eye spot development than the summer temperatures.

The knowledge of the temperature relationship to growth of the eye spot fungus will be available in other ways and will be referred to at other times. We feel very appreciative of the work of Mr. Halma and Dr. Fawcett in taking up this phase of our eye spot problem.

Summary

(1) Halma and Fawcett have shown that the eye spot fungus grows most rapidly at about 84° F. Growth is slower but continued longer at 68° and 74° F. At temperatures as low as 56° or 62° F. growth occurs but very slowly. At very high temperatures, also, growth is retarded; at 89° growth occurs but is very slow. At 96° F. the eye spot fungus makes no growth whatever.

(2) Although at sea level in the Hawaiian Islands the extreme minimum temperatures in winter are unfavorable for growth of the eye spot fungus, the mean temperatures in the winter months are very favorable. The extreme minimum temperatures occur in a very small percentage of the total hours in the winter months.

(3) Although the atmospheric temperatures in the summer months are not unfavorable to growth of the eye spot fungus, leaf temperatures in direct sunlight are 20° to 36° higher than atmospheric temperatures. Since growth of the fungus is more concerned with leaf temperatures than atmospheric temperatures, this point is of importance. Growth of the eye spot fungus is entirely inhibited at 96° F., according to Halma and Fawcett, and during a large percentage of the total hours in the summer months leaf temperatures of 96° F., or higher, occur.

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(H. A. L.)

Progress Report of Experiments with Fungicidal Dusts Against Eye Spot

By H. Atherton Lee and J. P. Martin

Although natural control by resistant cane varieties is the ultimate solution to prevent eye spot losses, there is a period of at least two or three years, or possibly ten years, before a satisfactory variety can be obtained and the H 109 areas with eye spot replanted to such a new variety. In this interim artificial methods for preventing eye spot must be employed, and by analogy with fungous diseases of other crops the use of fungicides is the measure which has most promise of success. Dust fungicides can be applied to cane fields with dusting machines at a reasonable cost, as we have shown (*The Hawaiian Planters' Record* for October, 1925; Vol. XXIV, No. 4, p. 377). Last winter, in cooperation with the Army Air Service, and in particular the personnel of Wheeler Field, experiments were tried with airplane dusting. Lieutenant O'Connell, of the Air Service, demonstrated that there was no obstacle to efficiently placing dusts on the cane fields in any situation. The experiments were carried on at the Oahu Sugar Company.

Coincident with these tests in methods of applying the dust, plot tests to determine the effect of various fungicides have been carried on. In the experiments six dust fungicides were tried out, the treatment with each fungicide having eight replications. The experiments were carried on in Field Mokuleia A-B of the Waialua Agricultural Company, where ample sources for eye spot infection were present.

The effect of the fungicides on the growth of the cane was observed by growth measurements and the increase or decrease of eye spot infection was observed by eye spot counts. For each plot ten stalks were used for growth measurements, or eighty per treatment. Eye spot counts were made on twenty stalks for each plot or 160 stalks per treatment.

The dusts were applied at two-week intervals commencing October 24, 1925, and closing February 25, 1926, there being nine applications in all for each treatment during the period of the experiment.

Of the six fungicidal dusts in the experiments, only one reduced eye spot. The results with this dust and two others are shown in the curves from the eye spot counts in Fig 1.

The curves in Fig. 1 show that eye spot started to increase on December 3 and reached the peak of infection on January 28. During this upward curve of eye spot infection the leaf counts showed the sulphur-treated plots with less disease fairly consistently. At the peak of infection, which is the critical time to reduce loss from top rot following eye spot, the amount of eye spot in the sulphur-treated plots was reduced 27 per cent as compared with the untreated plots. This reduction in eye spot was visible to the eye as well as by the eye spot counts. In the previous winter, 1924-1925, the sulphur-treated plots also showed less eye

spot visible than the control plots; the reduction was not complete prevention but must, nevertheless, have prevented a great deal of top rot.

There was no visible injury to the cane from the dust in the sulphur-treated plots as compared with the untreated plots. The growth measurements of the cane in all the three treatments and controls are shown in Fig. 2.

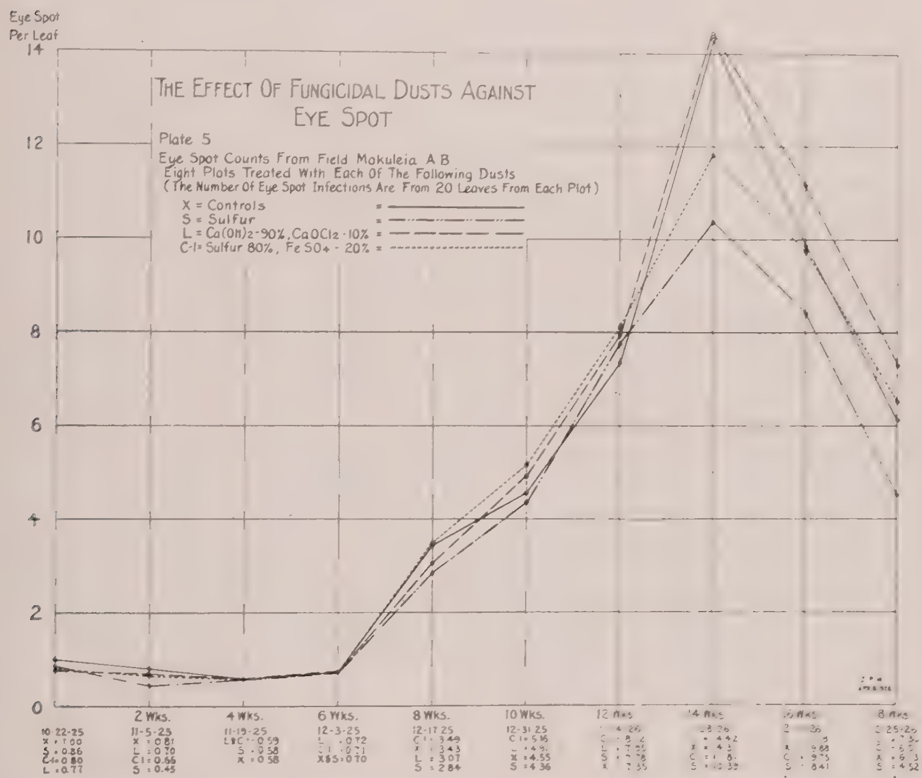


Fig. 1. Curves plotted from eye spot leaf counts in experiments testing fungicidal dusts. Each point on the curve is taken from 20 leaf counts per plot and there are 8 plots to each treatment, making 160 leaf counts per treatment. Note the beginning of the eye spot curve on December 3 and the peak of infection on January 28. At the peak of infection the sulphur-dusted plots showed 27 per cent less eye spot than the undusted controls.

In the foregoing tests the sulphur-dusted plots were at a disadvantage as compared to field dusting for the reason that each dusted plot was surrounded on all sides with heavily infected cane in the control plots or unsuccessfully dusted plots of the other fungicides. These other plots therefore afforded constant sources for infection of the dusted plots, which would be reduced by 27 per cent or more, if the dust was applied on a field scale. On a field scale dusting with sulphur would therefore be expected to be more successful than in the plot experiments just recorded.

Experiments with sulphur as a dust fungicide against wheat rust were carried on last year by the experiment stations in Manitoba, Minnesota and New York. The experiments were consistent in each place and showed a profitable

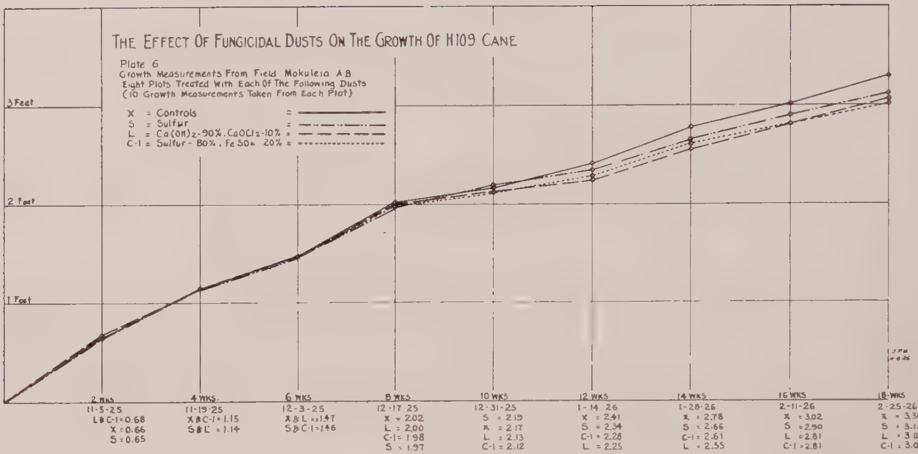


Fig. 2. Showing curves plotted from growth measurements of each treatment in the fungicidal dust test. There were 10 stalks measured per plot and 8 plots per treatment, making 80 growth measurements for each class of treatment. There seems to be little or no effect on the growth of the cane resulting from the fungicides.

reduction of rust by the treatments. In the experiment it was also shown that by increasing the dust applications from two-week intervals to only one-week intervals the reduction in rust was almost doubled.

In the coming winter the experiments will include a series of plots in which the intervals between sulphur treatments will be decreased. Adding other constituents to the sulphur dust is also being tried.

To the present time we have had no success against eye spot with the common dust fungicides containing copper, such as Bordeaux dust. The results with sulphur, although not completely effective, are sufficiently good to encourage us to try to improve upon it.

Appreciation is expressed to the Waialua Agricultural Company for their cooperation in carrying on these tests.

The Control of Eye Spot Through Resistant Varieties

By J. P. Martin and H. K. Stender

Previous to the winter months of 1924-1925 eye spot disease was considered more or less a minor cane disease although at times epidemics have developed in certain localities on susceptible varieties causing appreciable losses. With the recent increased planting of H 109 cane, especially in eye spot areas, the disease began to manifest itself and become a major cane disease.

The only final control of the disease will be effected by planting resistant varieties in those areas now affected with the disease. By removing the susceptible host the disease will naturally be reduced, thus offering greater protection to

entire plantations concerned. Some of the standard varieties such as Yellow Caledonia, Badila, Uba and Striped Mexican possess qualities of high resistance to the eye spot disease. These varieties could be planted in those areas of H 109 now badly affected with the disease but a sacrifice in sugar production would result because the sugar yield of these standard resistant varieties is considerably lower than that of H 109.

Showing the resistance to eye spot disease offered by Waialua seedling No. 1 as compared with H 109. Note that the disease has not only greatly retarded the growth of H 109 as compared with the seedling, but has killed a great portion of the H 109.

If crosses in breeding work are made with standard eye spot-resistant canes and H 109 cane, a few seedlings of the progeny of this combination should possess both qualities of eye spot resistance and high sugar production.

The following is a brief account of seedlings obtained by crossing H 109 cane with a very eye spot-resistant standard variety and also the potential possibilities of selecting a cane that will be commercially resistant to the disease and at the same time compete with H 109.

During the early part of 1924 this Station sent to Waialua Agricultural Company, Ltd., 400 young potted seedlings of that year's propagation. The parentage of these seedlings was three-quarters H 109 and one-quarter Striped Mexican.

Field Ranch 2B where the above mentioned seedlings were planted was quite severely affected with eye spot during the eye spot season of 1924-1925. Since the parentage of these seedlings gave promise of producing resistant canes, it was decided to make a detailed inspection of all seedlings and select only those possessing high degrees of resistance to the disease as well as good agricultural qualities. This selection was made the first part of March, 1925, at the peak of the eye spot

season. In all, nine seedlings were selected and carefully labeled for further propagation. These nine seedlings were selected primarily because they had developed so little eye spot in a very heavily infected area, and secondarily because they possessed good agricultural qualities. Y. Kutsunai and R. Conant, of this Station, made the selection on the agricultural basis while the senior author of this paper selected them because of their resistance to the eye spot disease.

The nine seedlings selected were numbered Waialua 1 to 9, inclusive, and were left to grow until November, 1925. At this date all available cuttings from each stool were carefully taken and planted in Field Gay 8A, which is located in another bad eye spot area. Equal amounts of H 109 cane were planted between the Waialua seedlings so a comparison could be made at all times.

The effect of eye spot on H 109 cane in the foreground as compared with Waialua seedling No. 6. Much of the H 109 cane has been killed from the disease, while Waialua 6 showed only a few minute infections which never developed large lesions.

All seedlings as well as H 109 germinated readily and numerous eye spot infections began to appear on H 109 and in lesser numbers on the Waialua seedlings. A few of these seedlings immediately began to show extreme resistance to the eye spot disease and maintained this resistance throughout the eye spot season. The seedlings in order of their resistance may be listed as follows: 1, 9, 6, 3, 8, 4, 5 and 7. Since eye spot became so severe in this area the growth of the young H 109 cane was greatly reduced and a fair comparison of growth between the Waialua seedlings and H 109 could not be made. All seedlings with the exception of Waialua 3, 5 and 7 were well ahead of H 109 in growth under the existing conditions. Much of the H 109 cane was killed by February 1, 1926, because of

the severe attack of eye spot. The resistance to the disease is well brought out in the accompanying photographs of two of these seedlings when compared with H 109. These photographs were taken at the height of the eye spot season by Twigg Smith.

Because of the promising possibilities of these seedlings further plantings from the best of these seedlings were carried out on July 20, 1926. All seedlings with the exception of Waialua 5 and 7 were planted to determine cane weights and juices in carload lots. To date nothing is known of the sugar content, ratooning qualities or other desirable qualities, but this experiment is well under way so that this information will be had at the earliest possible date.

In summarizing we can say that certain Waialua seedlings possess to a marked degree the desired eye spot resistance. These seedlings or others, if they prove satisfactory in other respects, may in the course of time be used to replace H 109 cane in certain areas which are at present badly affected with eye spot disease.

A Method of Testing Cane Varieties for Eye Spot Susceptibility and Resistance

By H. Atherton Lee, J. P. Martin and C. C. Barnum

It is appreciated by all, that natural control of insect pests or infectious diseases is the cheapest and most satisfactory preventive measure if entire exclusion of such troubles from the country has not been possible. In case of cane diseases the only effective natural control known at the present time is by the use of cane varieties resistant to such diseases. For eye spot prevention therefore, although attempts are being made for more immediate control, the ultimate preventive measures to be achieved, will be in the use of varieties resistant to eye spot and producing sugar yields as satisfactory as the present susceptible variety H 109. This is not as simple as may at first appear, for H 109, in addition to its high yields, is remarkably resistant to many forms of root injury and is tolerant to, and not readily infected with, mosaic disease.

In order to quickly recognize eye spot resistance or susceptibility in newly introduced varieties or new seedling varieties, a test has been developed which can be completed in ten days' time and which is also more accurate than most field observations; this method is called the eye spot index test.

Methods of Eye Spot Index Test

The method in principle consists in producing eye spot on the varieties to be tested by spraying the spores of the eye spot fungus on such varieties under conditions in which eye spot will develop. The amount of the resulting eye spot infection is compared with the eye spot infection on H 109 sprayed with the same spore infusion and exposed to the same conditions as the varieties under-

going the test. Usually the resistance or susceptibility of six varieties is determined in one test.

Collecting the Cane to be Tested

Ten stalks of a variety to be tested are cut in the field and the cut ends immediately immersed in fresh water. Usually, to get cane of approximately the same age, stalks are cut on which ten joints have formed. These stalks are transported to an eye spot cage where they are removed quickly from the water and placed in the sulphurous acid solution which has been developed by J. A. Verret

The eye spot moisture cage used in testing cane varieties for eye spot susceptibility and resistance. The sides and door are lined with burlap sacks. These were kept saturated at all times during the experiment. Note hygro-thermograph inside cage.

and his associates for holding cane tassels for breeding work. This solution consists of 1 part of sulphurous acid in 3,300 parts of water. During the gathering of the cane stalks it is essential to keep the leaves protected from the sun and wind, especially when the stalks are transported from any great distance.

Eye Spot Moisture Cage

The eye spot cage consists of a chamber with cloth sides, which can be kept wet, thus keeping the humidity in the cage high enough to maintain free moisture on the cane leaves. It is desirable to have the top of the cage covered with an opaque cloth such as burlap sacking, or a tarpaulin, in order to exclude the direct

rays of the sun from the cane leaves. This results in the cane leaves being slightly cooler than the atmosphere and in the condensation of moisture on the leaves rather than evaporation which occurs in direct sunlight. An illustration of the eye spot moisture cage is shown here.

Infusion of Eye Spot Spores

An infusion of the eye spot spores is next prepared in the following manner: The spores are taken from pure cultures of the eye spot fungus grown in Petri dishes on nutrient agar; the cultures are usually about ten days old and have been grown in total darkness. The infusion is made in tap water and a 3 mm. loop of the infusion is examined under the microscope, to be assured that the spores are present in sufficient quantity; it is desirable to have from 15 to 25 spores to such a drop. The same infusion is used for all varieties in a single test and the H 109 stalks used for comparison.

Hygro-thermograph in the Cage

The humidity of the eye spot cage is then raised to above 90°. A recording hygro-thermograph is maintained in the cage in order to be informed of the humidity and temperature conditions. The cane stalks and H 109 controls to be tested are then sprayed several times with the eye spot spore infusion, at three- to four-hour intervals. A rather large atomizer, called the Rose sprayer, is used for spraying the spores on the cane. Free moisture is maintained on the cane leaves for at least forty-eight hours following this inoculation in order to favor the germination of the spores and the penetration of the fungus hyphae into the leaf.

Methods of Taking Results

At the end of ten days, the eye spot lesions on the six youngest leaves of each of the ten stalks of each variety in the test are counted, measured and tabulated. The total lesions on variety A are compared with the total lesions on H 109, and so also for each of the other varieties in the test.

It is becoming more and more the trend in all biological reactions to endeavor to express results numerically or mathematically, since results so expressed are so much more accurate than by other means.

In the present tests, if we give H 109 susceptibility an empirical value of 1,000, then the number of eye spot infections on the ten stalks of variety A, is to the number of eye spot infections on the ten stalks of H 109 as X is to 1,000 and X will represent numerically the susceptibility of variety A; this may be expressed by the following equation:

$$\frac{\text{Eye spot infections on Variety A}}{\text{Eye spot infections on H 109}} = \frac{X}{1000}$$

The values obtained for X for the different varieties in the test are called the eye spot infection index numbers of such varieties.

Usually each variety is subjected three times to the above test. As an example of the above equation, ten stalks of the variety P. O. J. 36 after inoculation with eye spot spores, at the end of ten days in the eye spot cage, showed 157 eye spot infections as compared to 814 eye spot infections on identically treated H 109. The eye spot infection index for P. O. J. 36 would therefore be determined as follows:

$$\frac{\text{Eye spot infections on P. O. J. 36 (157)}}{\text{Eye spot infections on H 109 (814)}} = \frac{X}{1000}$$

$$X = \text{eye spot infection index of P. O. J. 36} = 192$$

However, many cane varieties although they become readily infected with eye spot, do not suffer from the disease, because the spots formed are small and the streaks or runners fail to develop. For this reason there are two types of resistance to eye spot; resistance to infection, and tolerance after infection. The foregoing method has been a measure of determining the susceptibility of a variety to infection; the following is a method of determining the tolerance of a variety after infection.

The tolerance index is obtained by measuring the length of all eye spot infections, plus the length of the streaks if they are produced; in other words the total lesions on ten stalks of the variety to be tested and comparing the total length obtained from such measurements, with the total length of lesions on ten stalks of H 109 under identical conditions.

Thus P. O. J. 36 in the test quoted above gave 157 eye spot lesions which totaled 1045 mm. in length. Ten stalks of H 109 under identical conditions yielded 814 lesions which totaled 4736 mm. The tolerance index would be determined as follows:

$$\frac{\text{Total length of eye spot lesions on P. O. J. 36 (1045)}}{\text{Total length of eye spot lesions on H 109 (4736)}} = \frac{X}{1000}$$

$$X = \text{eye spot tolerance index} = 220$$

P. O. J. 36 thus, has an eye spot infection index of 192 and a tolerance index of 220.

Results of Eye Spot Index Tests

The following are some of the results obtained from eye spot index tests to date, as shown in the following table:

Variety	First Test: Infection Index	First Test: Tolerance Index	Second Test: Infection Index	Second Test: Tolerance Index	Third Test: Infection Index	Third Test: Tolerance Index	Averaged Results: Infection Index	Averaged Results: Tolerance Index
H 109	1000	1000	1000	1000	1000	1000	1000	1000
P. O. J. 36	192	220	183	211	55	88	181	211
P. O. J. 213	0	0	0	0	44	18	2	0.1
P. O. J. 234	0	0	8	4	0	0	3	1
P. O. J. 979	126	61	13	10	0	0	73	40
U. D. No. 1	582	526	511	374	209	161	531	453
Yellow Caledonia	174	59	....	....	....	....	174	59
H 109	1000	1000	1000	1000	....	....	1000	1000
H 8942	824	671	483	344	....	....	511	381
H 8965	391	418	280	333	....	....	289	342
Uba	195	80	20	15	....	....	34	14
H 109	1000	1000	1000	1000	1000	1000	1000	1000
H 8994	216	51	281	96	285	85	261	77
Makaweli 3	308	67	56	22	185	45	183	45
Wailuku 8	1730	1204	1128	818	1878	1488	1575	1203
Wailuku 11	648	413	547	595	690	550	532	523
Wailuku 29	934	787	856	1072	974	911	921	890
H 109	1000	1000	....	....	....	....	1000	1000
H 8906	1132	921	....	....	....	....	1132	921
H 8952	360	82	....	....	....	....	360	82
H 8961	343	57	....	....	....	....	343	57
H 8988	775	444	....	....	....	....	775	444
H 89102	915	574	....	....	....	....	915	574
H 8993	275	47	....	....	....	....	275	47

The above table shows fairly consistent results for an extremely complex biological reaction involving factors such as climatic conditions where the cane was growing, condition of the cane as to vigor, viability of the fungus spores and other variables. In the case of two varieties the results have been thrown out, since they were not consistent and could not be depended upon.

From the results in the above table it may be said that P. O. J. 213, 234 and 979, Yellow Caledonia, Uba, H 8994, Makaweli 3, H 8961 and H 8993 are all commercially resistant to eye spot. These results illustrate the feasibility of obtaining varieties of strong resistance to the disease. Many such canes will be definitely inferior to H 109, but the yielding power of all such varieties should be carefully studied.

There are several varieties in the list which are susceptible, but much less so than H 109 and if planted in large blocks, away from heavy sources of infection would not suffer severely from eye spot. H 8965 and P. O. J. 36 are the most promising of such varieties.

Nevertheless there is no question but that a cane will ultimately be secured, satisfactory in yield and resistant to eye spot. The eye spot index tests described

here will permit immediate recognition of eye spot resistance in such a variety when it occurs.

SUMMARY

1. By collecting stalks of different cane varieties under comparable conditions and spraying them with spores of the eye spot fungus, it is possible to make a comparison of the susceptibility of such varieties with the susceptibility of H 109.

2. By giving an empirical value of 1000 to H 109 to represent its susceptibility it is possible to express numerically the susceptibility of other varieties in such tests.

3. The new varieties tested to date which show high degrees of resistance to eye spot are P. O. J. 213, 234, 979, Makaweli 3, H 8994, H 8993, H 8961 and H 8952. Such varieties as H 8965 and P. O. J. 36 are more susceptible but could be grown in fields with a history of eye spot with minor injuries if planted in large enough areas to be away from heavy sources of infection.

4. Of the standard canes being grown at present, which have been tested, Yellow Caledonia and Uba have shown the highest resistance to eye spot.

Credit should be mentioned for assistance in carrying on these tests to Messrs. Royden Bryan and Z. A. Romero.

Galls on Sugar Cane in Hawaii

BY H. L. LYON

During the past two years, considerable interest has been aroused at the Experiment Station by the appearance of overgrowths or galls on the stalks of many canes growing at the Makiki Plots in Honolulu. These galls have been the most numerous and attained the greatest size and complexity in certain seedling canes which are descendants of Uba, but they have also occurred at the same time on several other canes in the pedigrees of which Uba does not appear. We have made no extensive or intensive search for these galls on canes in plantation fields, but we have been able to find at least a few of them in every block of Uba seedlings of any size which we have examined. They have also been found in recent months on H 109 and other canes in plantation fields on Hawaii, Oahu and Kauai.

The appearance of external galls or tumors on cane stems is, by no means, a new phenomenon to us here in Hawaii and their occurrence on canes in Java was recorded many years ago. On all previous occasions (*except one*) when such galls were noted in Hawaii, they were few in number on the individual sticks and the affected sticks were widely separated in the fields. The cases have always been sporadic or transitory, or confined to a single variety of cane. In view of

these facts, we were forced to view them as freaks such as may be found on occasion in any variety of plant and due to temporary derangement of the vital mechanism which controls the growth of the plant.

In the present instance, however, galls have been found in varying numbers on many varieties of cane within a restricted area. In several varieties, they have appeared continuously and in great numbers on every stick; and, in a few varieties, their development has proceeded to such an extreme as to render the canes quite worthless for commercial purposes. Such circumstances call for a radical revision of our former conclusions regarding the causation of these galls, for the evidence now at hand would seem to indicate that we are dealing with a malady caused by some factor quite foreign to the vital mechanism of the cane plant since it operates simultaneously on many individuals of many different varieties.

Nature and Distribution of Galls

As a rule, these galls develop as superfluous appendages on nodes and internodes that are apparently normal in all other respects; shave off the galls and you have left normal-appearing canes. In some aggravated cases, however, the development of the external galls is accompanied by more or less distortion, displacement and atrophy within the tissues of the members from which they spring and a conspicuous monstrosity is the result.

In the majority of affected canes, nodes and internodes of normal shape and structure are differentiated in proper sequence from the growing point of the stem. While their tissues are still near-embryonic, i. e., before they have become completely transformed into permanent tissues, groups of cells at and near the surface break from the course of development required of them by their position in the stem and, multiplying rapidly, produce an excess of tissue which protrudes beyond the normal surface of the stem as an overgrowth or gall. When the rudiments of the galls are first discernable with a low-power hand lens ($\times$ 10), they look like delicate water blisters, some standing singly and others running together in variously shaped groups. These blisters soon grow into galls of the most irregular and diverse shapes. The forms assumed include threads, ridges, plates and nodular masses with galls of each type distorted in every possible manner. The tissue in the young galls is all embryonic or meristematic and consequently very delicate. It would shrivel up very quickly if exposed to the air, but since the galls begin their development on very young nodes and internodes, they are protected for a long time by the overlying leaf sheaths. They are, therefore, required to pass through their early development in very restricted quarters and, being more or less plastic throughout this period, their shape is determined, to a considerable degree, by the leaf sheaths which closely cover them. As a result, the young galls are always more or less flattened against the stem. It is not uncommon to find a large, flat gall connected to the cane stalk by a very small neck of tissue which indicates the size of the initial protuberance.

Galls may develop at any point on a node or internode not occupied by a leaf or bud, but they spring most frequently from the root band and stem node; regions in which the tissues retain their meristematic properties longer than do

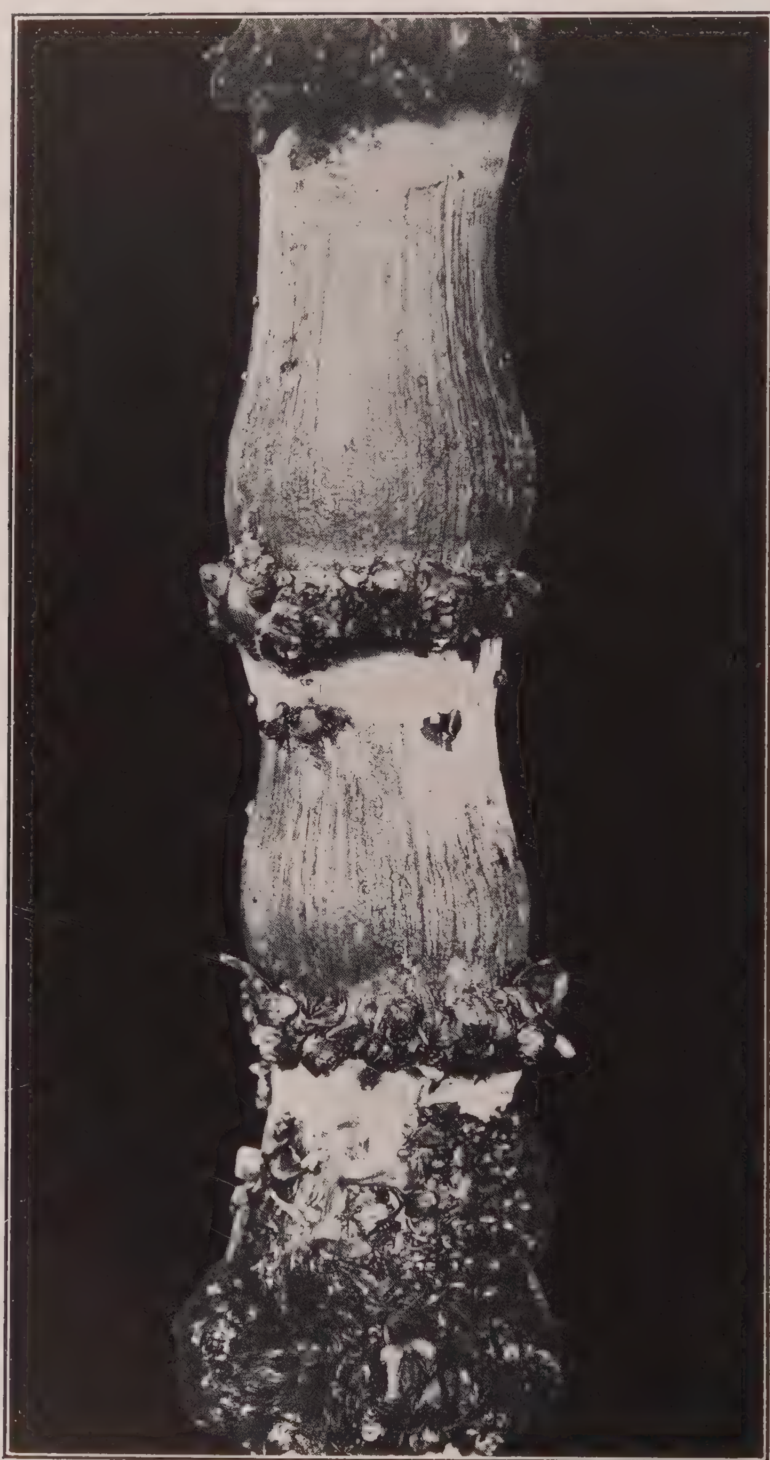


Fig. 1. A stick of U. D. 47 showing an extreme case of gall production. The lowermost internode shown in the picture is covered with galls while the other two internodes are badly deformed.

the tissues of the internode. In severely affected canes, it frequently happens that all of the superficial tissue of a root band and the adjoining stem node becomes involved in the production of galls. In such canes, galls may also appear on the outer surface of the leaf sheath and on the outer scales of the bud.

Some galls attain a large size without undergoing any appreciable differentiation, but many of them show a tendency at an early stage in their development to elaborate leaf tissue. This is most often evidenced by the production of thin plates of tissue in which strands of vascular tissue may be differentiated with each strand surrounded by mesophyll cells.

An entire gall may become transformed into a folioid structure or it may simply develop one or more folioid appendages. In some canes in which gall production has become chronic, the galls on the root bands and stem nodes regularly become very large and as regularly differentiate into adventitious buds which are exactly comparable to normal buds and, like them, may develop into leaf-bearing shoots. Adventitious buds are very rarely differentiated out of galls springing from an internode. When a lateral stem gall gives rise to folioid structures without first differentiating a bud or growing point, these structures never attain any considerable size and do not approach in any degree the complexity of a leaf. They are, as a rule, very thin and frail, quite devoid of any semblance of a midrib and, in fact, only comparable in structure to the auricle of a leaf.

The ultimate size and complexity which a gall may attain seems to be determined more or less definitely by the stage of development which it reaches before it is exposed to the air and light by the falling away of the overlying leaf bases. A gall is an exogenous outgrowth and, unless it organizes a bud and thus protects a growing point with scale leaves, its meristematic tissue is fully exposed to the air when the leaf sheaths fall away. Under ordinary weather conditions in Honolulu, such tender gall tissue, when exposed to the air, either passes over quickly into permanent tissue or dries up and dies. Such drying is not confined to the meristematic tissue only, for many of the folioid structures also dry up and the sticks bearing them look as though they were covered with dry, brown scabs. Buds which have been organized out of gall tissue and exposed by the falling away of the leaves may continue their growth and, under favorable conditions, develop into normal shoots.

As previously noted, the entire root band may be involved in the production of galls and this leads to the obliteration of all of the primordia of adventitious roots normally laid down in this region. It seems that the factor inducing gall production tends, at the same time, to lessen or suppress the normal tendency in the stem to produce adventitious roots. At any rate, we have had difficulty in getting badly galled cuttings to produce a sufficient number of roots to supply the needs of the aerial shoots which spring from them.

It was early noted that, in canes severely affected by the malady, incipient galls could be easily detected on the tender tissues within half an inch of the growing point of the stem. This suggested the question: what would be the result if the growing point of the stem were taken with a spasm of gall production? Would it not be a malgrowth such as we have previously known and described

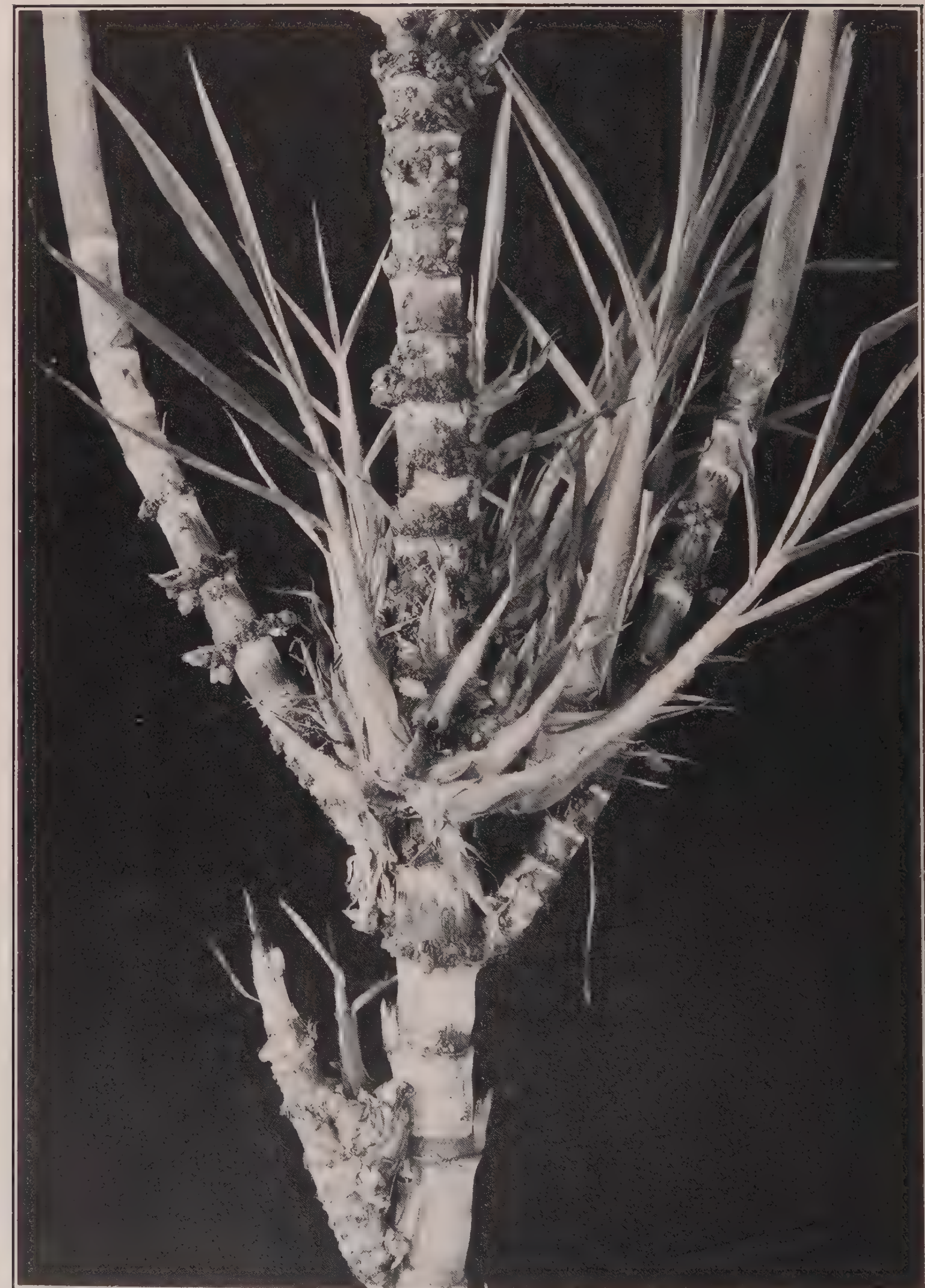


Fig. 2. A stick of U. D. 47 heavily infested with galls, many of which have given rise to adventitious buds and some of these have developed into leafy shoots.

Fig. 3. A badly galled stick of U. D. 47 bearing a great cluster of closely set shoots which have developed from adventitious buds.

as bunch-top? To answer these questions, we set about to dissect out the growing points of a large number of sticks, choosing such as were severely affected with galls on their exposed parts. Our search resulted in bringing to light several cases of bunch-top in initial stages of development. This not only tied up the malgrowths known as bunch-top with the malady now under discussion, but gave us information regarding the development of these malgrowths which we had previously sought, but never been able to obtain.

When many of the badly galled canes at the Station were cut in March, 1926, a casual survey was made for bunch-top and many cases in advanced stages of development were detected. Sufficient evidence was obtained to fully demonstrate that bunch-top is a gall of the same nature as the lateral stem galls, but much more elaborate because more embryonic material is involved to start with and conditions are more favorable for its continued development. Being terminal, it enlarges into the space normally occupied by the spindle of leaves and so its development is not at any time checked for want of room.

A great variety of these terminal galls or bunch-tops have been found and examined and, no doubt, many more forms will be met with in the future. In general, they behave as do the lateral stem galls in that they produce leaf-like structures and buds. The folioid structures sometimes reach a length approximating that of the normal leaves and they sometimes show almost or quite as complete differentiation into tissues; more often, however, they are quite devoid of a midrib or any semblance thereof. When terminal galls differentiate buds, these may at once grow into shoots bearing normal leaves.

Specimens of bunch-top thus far met with range from a bundle of strap-shaped folioids to a bundle of closely set shoots. Between these two extremes, we have mixtures of strap-shaped folioids and leaf-bearing shoots in various proportions. It is not uncommon for a bunch-top to produce a terminal bud which grows up beyond the gall as a normal-appearing shoot or stick. In rare cases, two or three buds may develop and grow side by side into shoots. The result is a bifid or trifid stick with a distorted section at the point of branching, this section being marked with several or many small, oblique and otherwise abnormal leaf scars. See Figs. 6 and 7.

Sticks showing no galls whatsoever at any other point may develop a bunch-top and we have found cases of bunch-top in one variety, U. B. 3, Fig. 7, of which no sticks have ever been found bearing any other type of gall.

Cane Galls at the Experiment Station

Of the many canes growing on the Makiki Plots in Honolulu, galls have been found during the past ten months on the seventy-four varieties listed hereunder:

U D series, Nos. 13, 14, 20, 21, 22, 25, 28, 29, 30, 32, 33, 35, 39, 40, 47, 56, 60, 67, 68, 70, 75, 80, 88, 92, 99, 106;

25 Q series, Nos. 12, 15, 26, 77, 88, 104, 105, 110, 112, 116, 117, 137, 165, 206, 222;

24 H series, Nos. 16, 40, 59, 65, 71, 81, 93, 100, 107, 120;

25 C series, Nos. 5, 9, 15;

Fig. 4. Bunch top. This specimen was figured and described in the *Record* in 1910. Vol. II, No. 6, pp. 341-342.

Fig. 5. Bunch top. This same cut was used in our paper on "Sereh" published in 1921. Bull. of the Exp. Sta., H. S. P. A., Bot. Series, Vol. III, p. 29, 1921.

1918 O. P. 328, 1919 O. P. 561, 1919 O. P. 803, 1919 O. P. 822, 1920 O. P. 296, 1920 O. P. Special 2, 1920 O. P. 593, 1924 O. P. 47, H 109 x D 1135, H 109, H 9921, Puaole, Ewa 800, Ewa 801, Wailuku 1, Wailuku 9, Makaweli 1, Honokaa U H 3, 26 Q 235, U B 3.

Uba is a parent or grandparent of forty-four of the canes enumerated above. The other thirty varieties are derived exclusively from big-stick canes: Puaole is a native Hawaiian cane and the rest are seedlings of Lahaina, Striped Mexican, Yellow Caledonia and D 1135.

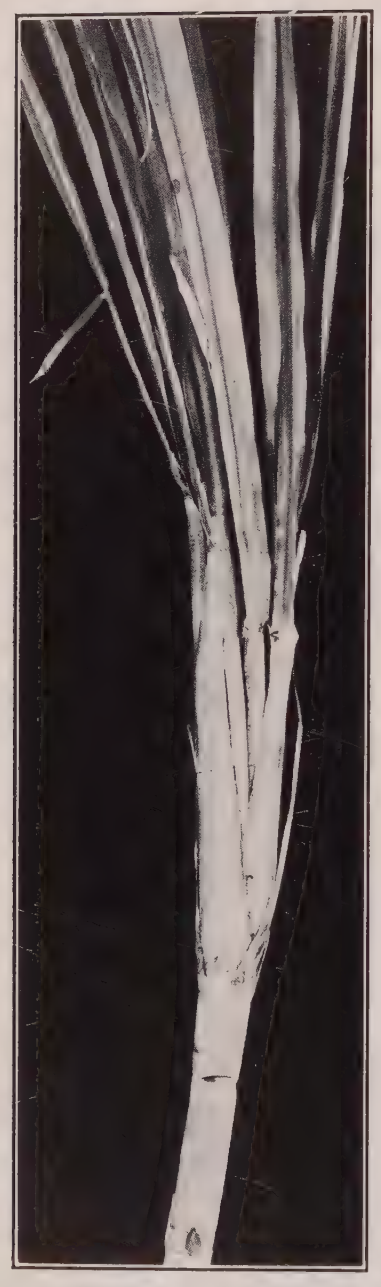


Fig. 6. Bunch top in U. D. 67. Except for their rather narrow sheaths, these leaves are normal, each having a well developed midrib.

Fig. 7. Bunch top in U. B. 3. The number of folioids elaborated may be noted from the leaf scars. In the case on the left, two buds developed as growing points, producing a bifurcated stick, while a single bud grew out from the bunch top on the right.

These canes do not, by any means, suffer equal injury under the attacks of this malady. In many of the seventy-four varieties listed above, galls have been found on a very few sticks only and in the majority of these cases, the galls are small and so widely scattered as to render detection difficult, while the individual sticks bearing them are not appreciably affected.

In several of the varieties, however, gall production has become epidemic and chronic; galls appearing continuously and in great numbers on every stick. Up to the present time, U D 47 and U D 67 have been the most severely affected canes and these two varieties were eliminated from our cultures at the Makiki Plots in March, 1926.

Galls in varying numbers have been found on H 109 in eight separate plantings at the Station; two of these being plantings of selected progenies.

Galls on Imported Canes

In June, 1925, a proliferating gall was discovered on a stick of P. O. J. 2714 growing in the quarantine house at the Pathology Plot in Honolulu. The stool bearing this stick was promptly condemned by the pathologists and destroyed. A few weeks later, a similar gall appeared on a stick of P. O. J. 2725 growing in the same house and all of the canes then in the Quarantine House were destroyed as a precautionary measure.

Galls on Canes in Hawaii in Former Years

Small, nodular or folioid galls similar to those now appearing on our canes at the Experiment Station have been seen on sticks of the standard cane varieties in Hawaii at various times during the past twenty years. As previously stated in this article, these galls have, except in one case, always appeared singly or very few in number on isolated sticks and were consequently given very little consideration. The one exception was supplied by a seedling cane raised and propagated on Maui. In May, 1920, W. W. G. Moir sent from Maui to the Station, for examination, a stick of cane literally covered with nodular and folioid galls. E. L. Caum was sent over to Maui to examine this cane further in the field and to secure additional material for study. In a letter dated June 1, 1920, Mr. Caum wrote from Wailuku as follows: "It is a seedling of H 109, No. 44914 grown at Wailuku and planted in Field D, H. C. & S. Co. In the 15-foot row, there were thirty sticks, twenty-seven of which showed the wound-tissue in some degree." These sticks were badly infested with acari and we concluded at that time that the galls were induced by the mites. The particular seedling affected was discarded.

While working at Waipio substation in 1920, Messrs. Caum and Moir discovered a single stick of H 240 bearing large galls on two root bands. One of these galls had already developed several large buds. A photograph of this specimen is reproduced herewith as Fig. 8. The large bud-bearing gall was cut from the stick and planted at the Makiki Plots. It gave rise to a normal stool of cane which persisted until 1926, when it was dug out and destroyed. Galls were never noted on any of the sticks arising from this stool.

Fig. 8. Galls on H 240. The large gall on the right side of the middle node bearing several adventitious buds was planted and gave rise to a normal stool of cane.

Bunch-tops have also been found in Hawaiian cane fields at intervals during the past twenty years. They are always conspicuous objects in a cane field because of their large size and peculiar composition and consequently are more easily detected than are the lesser nodular and folioid galls which occur as lateral outgrowths on the stem.

During the spring of 1910, bunch-tops appeared in considerable numbers on several varieties of cane and on widely separated plantations. They attracted much attention and caused considerable apprehension as some observers were inclined to consider them malgrowths induced by sereh. After studying sereh in Java, we were able to say very definitely that bunch-top had no connection with this disease. It then appeared to represent a separate and unique problem in cane pathology. In 1921, we offered the conclusion that "Bunch-top is a malgrowth resulting through the abortion of an inflorescence or tassel. The growing point of the shoot reverts to vegetative growth after starting the development of an inflorescence, and a bunch-top is the result."

In the light of our present knowledge, we must withdraw this conclusion and place bunch-top in the category of a gall induced by extraneous forces.

Galls on Canes in Java

When we visited Java in 1911, we carried with us illustrations of bunch-top. These we submitted to Miss G. Wilbrink, pathologist at the East Java Experiment Station, and she informed us that nothing of the sort had, to the best of her knowledge, ever been seen on canes in Java. No specimens approximating bunch-top were to be found in the museum at the Experiment Station, but several well-preserved specimens showed lateral galls on the nodes, internodes and buds. Some of these galls had organized folioid outgrowths and others had given rise to adventitious buds. One specimen which particularly attracted our attention showed gall tissue arising throughout the entire extent of practically every root band with each mass of gall tissue giving rise to many adventitious buds. A photograph of this specimen is reproduced herewith as Fig. 9.

Miss Wilbrink called to our attention an article by Kamerling, which had been published in the *Archief* in 1900. In his paper, Kamerling describes and illustrates galls on cane which are in every way identical to those occurring on our canes here in Hawaii. Immediately following this paper will be found a translation of Kamerling's article prepared by W. van H. Duker.

When Miss Wilbrink visited Hawaii during April and May of the present year, she was shown canes bearing galls and she stated that the galls were of exactly the same nature as those which she had often observed on canes in Java.

After discussing this subject in all of its various phases, Miss Wilbrink gave us the following interesting statement:

> One Chunnee seedling raised at the East Java Experiment Station and selected for propagation developed the habit of producing adventitious buds very freely around its nodes much after the fashion shown in the illustration, Fig. 9. This rendered the seedling worthless for commercial purposes and it was never spread to any extent. Superficial galls have been found on sticks of 247 B, but their occurrence on this variety is very rare.

Fig. 9. A specimen preserved in the museum in the East Java Experiment Station. A ring of adventitious buds surrounds each node.

Galls occur much more frequently on sticks of 66 B, but even on this variety they can never be said to be really numerous. You can usually find them in any field of this variety, but they do not occur on every stick by any means and are, as a rule, small and scattered, not clustered together.

A portion of a stick of P. O. J. 2714, bearing a great mass of adventitious buds on one side of a node was once sent to the Cheribon Station for examination. The buds were closely clustered approximating the arrangement of the eyes of a pineapple. This is the only case of proliferation in this variety which has come to my attention. I never saw a case of proliferation in P. O. J. 2725.

The Causal Factor Unknown

Various opinions and theories have been advanced to explain the production of galls by our canes, but none of these has, as yet, been supported with anything like adequate proof.

The general appearance of the galls, their position on the stem and their proliferating tendencies suggest at once the familiar crown galls: monstrosities which are caused by infection with a bacterial organism, *Bacterium tumefaciens.* To the best of our knowledge, however, crown galls are not known to occur on grasses or, for that matter, on any other monocotyledonous plant, but they do occur on a great many dicotyledonous plants. We have found bacteria in cane gall tissue and in stem tissue adjacent to galls, but we have not, as yet, demonstrated that they have any connection with the genesis of the galls.

All canes in Hawaii are more or less infested with acari, tiny mites or spiders which live under the leaf sheath and induce the formation of minute galls on the stem and sheaths. These tiny galls and the mites responsible for them have been known for many years in Hawaii and other cane-growing countries. It was quite natural, therefore, that we should suspect them of causing the development of a larger gall on occasion. When Mr. Moir sent badly galled canes to us from Maui in 1920 and we found them heavily infested with these mites, we at once concluded that the particular seedling cane in hand was extremely sensitive and reacted more strongly to the irritation caused by the mites than did the usual run of canes. In galled canes recently examined, however, we find that galls often begin their development and, in some cases, attain a considerable size, before the acari penetrate to their locations.

Proliferating galls were first noted at the Experiment Station on several of the U D seedlings and it was suggested by some observers that the galls were but an expression of the incompatibility of hereditary characters derived from two so unlike parents as Uba and D 1135. When a careful survey of all of the canes in the Station fields revealed galls on such varieties as Puaole, H 109 and Wailuku 1, however, this convenient hypothesis was seriously weakened.

To the best of our knowledge, galls have never been found on the Uba cane. They have, however, been found in varying numbers on many varieties of the big-stick race of canes. It might be argued then that gall production is a latent or suppressed character in these latter canes but becomes active in some of the varieties obtained by crossing these big-stick canes with the slender Uba. If this hypothesis could be substantiated, we could view gall production as simply an objectionable character to be eliminated by breeding.

While considering these interesting theories, we must not loose sight of the fact that much of the evidence recently obtained seems to indicate that these proliferating galls are the outward symptom of an infectious disease. Should this prove to be the case, then there is potential danger in the present situation and immediate and thorough investigation of the malady is imperative. We can easily devise and put into operation defensive measures that will be very effective now, but of little avail at a later date when the disease has become generally spread throughout the Islands. It is very important, therefore, that we determine, as soon as possible, the nature of the forces causing these galls on our canes. If they are inherent, we can breed them out of our cane: if they are extraneous, we must detect their character and take measures to protect our canes against them.

Adventitious Buds on Sugar Cane*

By Z. Kamerling

Translated by W. van H. Duker

A new organ of a plant, such as a leaf, bud or root, generally develops out of a tissue which has no definite function yet in the plant-organism, of which the cells have not yet assumed a specific shape in connection with the function to be performed. Such a tissue shows no, or a very minor, distinction between the various cells, which, in connection with their specific function, show a very different construction later on; they are, so to say, undeveloped. An artificial term for such tissue is meristem.

Every growing point both of the stem as well as the root consists of meristem. It does happen, however, that new buds or roots develop out of already fully developed tissue and in such cases we speak of adventitious growths.

Under normal conditions, no buds or roots grow on a leaf, the cells of the full-grown leaf are already shaped in a definite way in relation to some function which they have to perform either as tegumentary or chlorophyllus tissue. Yet, adventitious buds do sometimes develop out of already full-grown cells and grow to new plants as in the case of leaves cut from the Begonia and a few other plants. Adventitious roots grow on the bark of certain shrubs and trees if kept in moist soil and if adapted to be spread in this manner.

Especially, adventitious roots grow easily on many plants and, as a rule, the characteristics of forming adventitious roots and adventitious leaves indicates whether or not a plant can be spread by cuttings.

On a recent visit to Kremboong, Mr. Moquette called my attention to a peculiar growth on some cane varieties raised by him, and a closer examination proved that we were dealing here with a case of adventitious buds. Mr. Moquette kindly

* From *Archief voor de Java Sukerindustrie,* Vol. I, pp. 57-61, 1900.

supplied me with sufficient material to study the younger development stages of this peculiar phenomenon.

Stalks which show this abnormality strongly have, besides the normal buds (which, as far as I investigated, were always present), some large lumps in the

Fig. 1. Illustration used by Kamerling and referred to in his text.

vicinity of some of the buds which, in some cases, grew apparently normal shoots. On closer examination, it turned out that the entire lump was covered with partly sprouted buds and sometimes with roots in between. These buds showed no regularity whatsoever in their arrangement. Some were normal (that is, the point was in the direction of the top of the stalk) ; others had a slanting position, and again, others were turned upside down. As soon as these buds begin to sprout, the young shoot grows in a vertical direction, upwards, just like normal shoots.

Fig. 1 is a reproduction of a photograph taken by Mr. Moquette and shows the lump. As far as I am aware, there is only one variety which shows this peculiarity badly and it happens to be a variety of no great importance commercially, the seedling No. 397. In this variety, this peculiarity occurs so frequently that in the comparatively small area of the seedling plot at Kremboong, several instances could be found without any difficulty, showing the peculiarity in no less degree than the stalk in Fig. 1. If the abnormality occurs in lesser degree, the small lumps are covered with fewer buds or sometimes with but a single bud.

Fig. 2 shows a piece of cane with, to the right of the normal bud, a lump covered with small scales and an adventitious bud.

Fig. 3 shows a similar adventitious bud which begins to develop while still attached to the stalk; we see here how the young shoot, while originally growing downwards to the right, already starts to grow upwards.

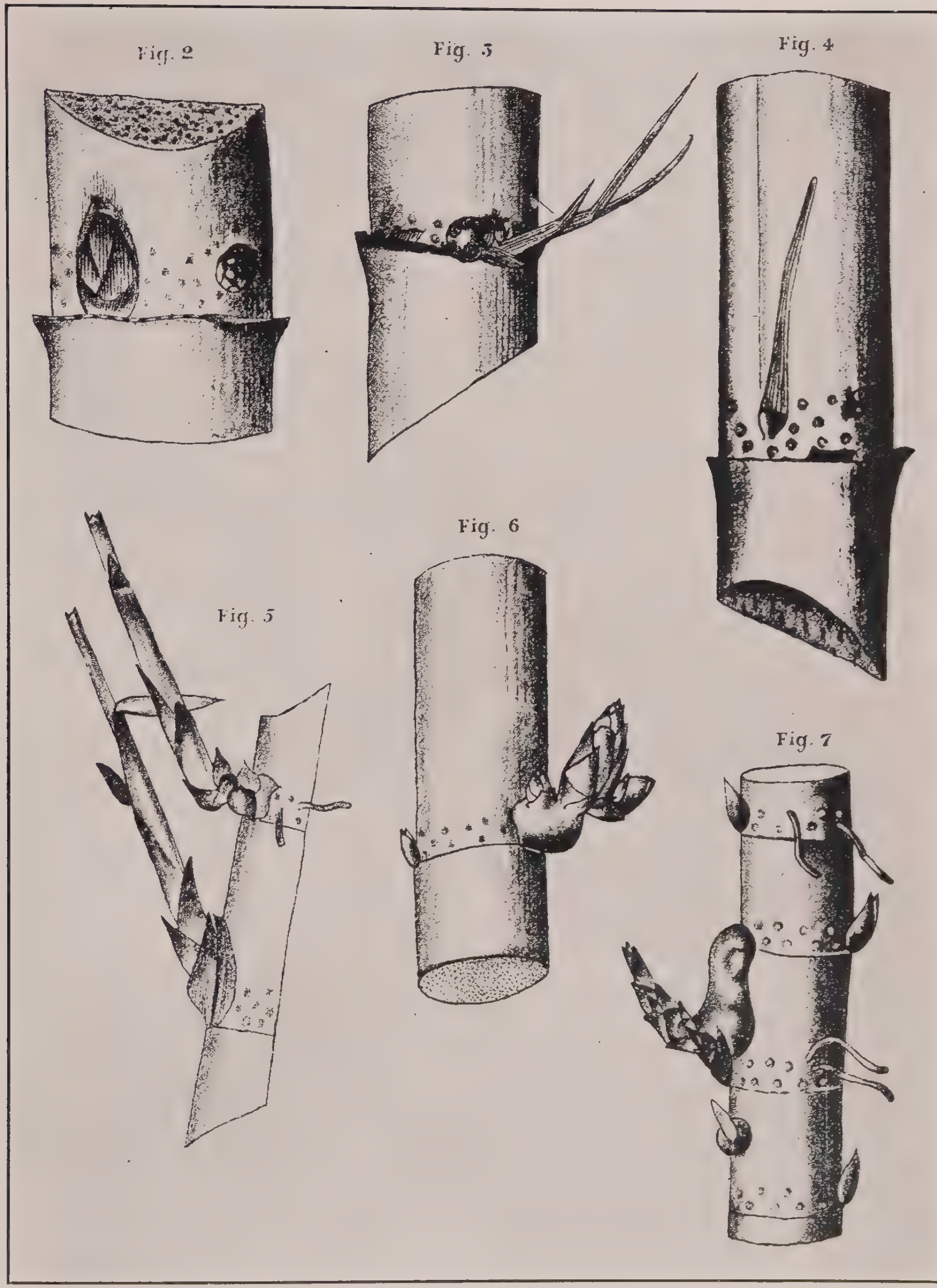
Fig. 4 shows a piece of cane with two such adventitious buds; in one case, we note a long scale and a groove such as occurs with normal buds. We can see in the illustrations of Figs. 2, 3 and 4, the adventitious growths not only differ from the normal buds in position but in shape as well. They are not regularly shaped buds, but more or less irregularly shaped lumps covered with irregularly placed smaller or larger scales.

Especially if we follow up the development, we note an irregular growth which, in some instances, grows out into a small shoot; in other cases, to comparatively normal buds which then continue to develop.

In Fig. 5, the upper one of the two sprouted buds is an adventitious bud as can be considered by observing the position in relation to the other buds on the same stalk; it has a kind of stem and is grown on the top of a small lump. The young shoot is entirely normal.

Fig. 6 shows a similar group of three adventitious buds, each by themselves. They are normal, but the place on the stalk, the grouping and the fact that they do not come directly from the stalk, but are placed together on a lump, indicates an abnormality.

The illustration in Fig. 6 is not of the seedling No. 397, but of No. 66, which shows this abnormality from time to time. The material of this variety I also collected at Kremboong. On lumps such as shown in Fig. 1, we always find both types of adventitious buds, both the normally shaped (which, however, show their characteristic as adventitious buds by their unusual position on the stalk and on top of a lump) and the irregular small lumps more or less covered with scales which, because they sometimes develop as shoots, are characterized as buds.



Figs. 2 to 7, inclusive. Illustrations used by Kamerling and referred to in his text.

The latter sprout but seldom, and, if they do (Fig. 3), the shoots are weak and poor, whereas the shoots from normally developed, adventitious buds grow just as well and forceful as normal buds on the same stalk.

Fig. 7 shows a piece of a stalk of the variety No. 397, which is also of interest. In the center of the three joints can be seen how the normal sprouting bud is pushed aside and forward by a large lump which has formed on the same joint. On this lump is another fairly normal adventitious bud in a rather advanced stage of development. On the lowest joint is a similar lump, as in Fig. 4, also covered with a large scale. Considering what might be the cause for the formation of such adventitious buds, I first took the lumps for wound tissue (callus). It often happens (not so much on coconut or palm trees, but very pronounced on mango trees) that the wound edge thickens and that the wound surface becomes slowly over-grown. On such callus adventitious growths are frequently found. and my first thought was that the lumps might be caused by small cracks in the stem and that the adventitious buds grew on top of these.

However, this idea proved to be wrong, because in examining the early stages of development of these lumps, I found the epidermis not touched and perfectly sound, and also that the tissue development begins in the interior of the stalk a little under the epidermis. So far, we do not know what causes these peculiar growths. The structure seems to indicate that it is a pathological case because in the consequent development stages, we find strong gum secretions in the vessels and between the cells, and gum formation does not occur in healthy cane plant tissue.

But a disease in the ordinary sense, it is not either, because the cane is otherwise perfectly healthy and the adventitious buds do at least sometimes develop in otherwise normal plants. Nothing has shown so far that this development of adventitious buds is in any way contagious, but it is heritable, as is quite common with similar abnormalities. Mr. Moquette stated that it recurs every year in this variety No. 397, and as far as I know, it has only been observed in the two before mentioned varieties, in No. 66 sporadically and in No. 397 frequently.

This appearance of adventitious buds cannot be mistaken for the peculiarity of two perefctly normal buds appearing in the place of a single bud. These double buds, which otherwise are very rare, I found in Cheribon and Muntok cane.

(H. P. A.)

Studies on the Pathological Nature of the Uba Node Gall Disease

By C. C. Barnum

It is possible to report a few definite results of experiments with the so-called node gall disease of the U. D. varieties. In studies to determine the infectious or non-infectious nature of this disease, gall tissues or warts from U. D. 47 cane

badly affected with node galls were ground finely and the liquids extracted in a press exerting 1,000 pounds per square inch. Inoculations were made in healthy stalks of H 109, D 1135 and U. D. 14 canes. Controls with sterile tap water were made at the same time. In 26 days no galls were produced on the H 109 or D 1135 canes. Both the controls and inoculated stalks of U. D. 14 were equally affected with gall tissues at the close of 26 days' incubation period.

Healthy stalks of Uba and U. D. 47 cane growing at Manoa substation were inoculated with gall tissue from diseased U. D. 47 cane. Neither controls nor inoculated stalks developed galls in 26 days' incubation.

The conclusion drawn from these results is that node galls are not readily transmitted by direct contact. In other words the disease is not highly infectious under the conditions of the experiment, which were normal field conditions. On the other hand we have diseases of plants such as mosaic disease of cane and curly top of sugar beets which are not directly transmissible under usual field conditions, but which are nevertheless infectious when the proper insect vectors are present. Further studies are necessary to determine whether these node galls are in the class with abnormalities which are regarded as inherent genetic characters or constitute one of the diseases with insect vectors or other obscure means of transmission.

Progress Report on the Distribution of Cane Roots in the Soil Under Plantation Conditions

By H. Atherton Lee

In studying root rots in connection with the different types of Lahaina growth failure, it became necessary to understand the normal root system in order to be able to properly appreciate the nature and seriousness of root injuries. This led to the studies of root distribution in boxes reported in *The Hawaiian Planters' Record* for April, 1926 (Vol. XXX, No. 2, p. 267). It became apparent, however, that results under actual plantation field conditions would be much more satisfactory, so that a method of determining the distribution of roots was devised. As the studies have progressed it has become evident that the results are not only of value in connection with studies of root injuries, but they also have a value, in that exact knowledge of the distribution of the roots in the soil leads to a more intelligent understanding of the problems of tillage of the soil, cultivation, irrigation and fertilization.

Method of Determining Root Distribution in the Soil

Five representative stools of cane are selected, the cane is cut back, and the ground leveled to the junction of the stubble with the soil. A rectangular area is staked out extending 2½ feet on each side of the cane row to contain the five

stools to be studied. The rows being 5 feet apart, any roots of the plants being studied which extend beyond the sides of the excavation, are compensated for by the roots extending into the excavation from the cane rows on either side. An excavation is then dug in this staked area to a depth of 8 inches. In removing the soil from this area, the earth is thrown on a wire screen, ¼ inch mesh, and sifted through the screen; the cane roots are removed as they become separated from the soil on the screen. The roots from this 8-inch layer are collected, placed in a bag, and following this, the roots from the layers of soil 8 to 16 inches in depth and 16 to 24 inches in depth and so on are collected separately. The roots are then washed, oven-dried and weighed.

Fig. 1. Showing the excavation which is made to secure the roots of the cane, and the screen on the right through which the soil is sifted and the roots separated. Photograph by W. P. Alexander, of Ewa Plantation Company.

No stubble is included in the tabulation; where any appeared on the screen the roots were trimmed off and preserved, and the stubble discarded. The screen in use and the character of the excavation are shown in Figs. 1 and 2, which were made from photographs taken by W. P. Alexander, of Ewa Plantation.

To demonstrate the working of this method the following first few determinations of root distribution are presented.

Some of the Results With This Method

The first determination under this method was made on H 109 plant cane, 10½ months old, growing in Field G of the Waipio substation. This cane had had 28 irrigations and had received 275 lbs. of nitrogen and 175 lbs. of phosphoric acid, but no potash. The following results were obtained:

Fig. 2. This shows the screen more fully, on which the roots are separated from the soil after excavation. The paper bags into which the roots are placed are shown beside the screen. Photograph by W. P. Alexander, of Ewa Plantation Company.

TABLE I

Depth in Soil	Average Weight of Roots per Stool in Grams	Percentage of Total Roots
Topmost 8 inches	135.23	70.14
8 to 16 inches	43.92	22.78
16 to 24 inches	11.34	5.88
24 to 30 inches	2.29	1.18
Totals	192.78	99.98

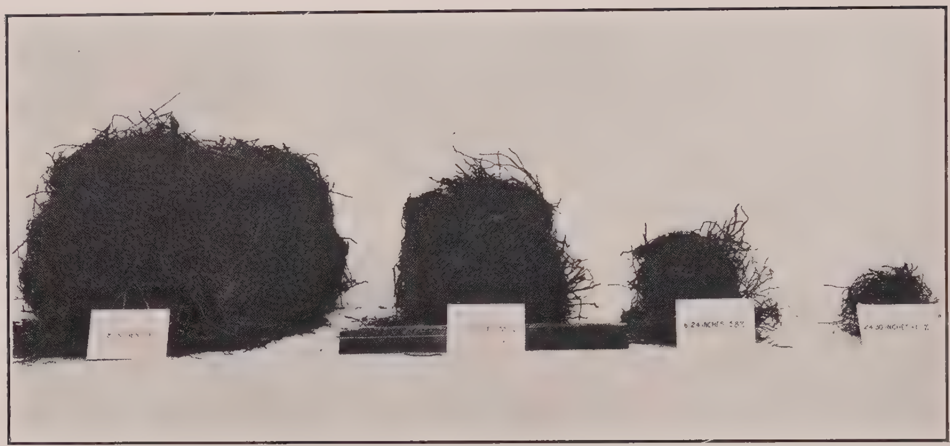


Fig. 3. Showing graphically the comparative masses of H 109 cane roots at different levels in the soil in Field G at the Waipio substation. The root mass in the topmost 8-inch layer of soil is a lighter brown color because of the greater proportion of small secondary actively feeding roots which are a lighter brown color than the older primary roots.

Fig. 3 shows these same results in a more graphic form.

A determination using five stools of Yellow Tip cane, 26 months old, unirrigated, from Field H 36 of Lihue Plantation Company, gave the following figures:

TABLE II

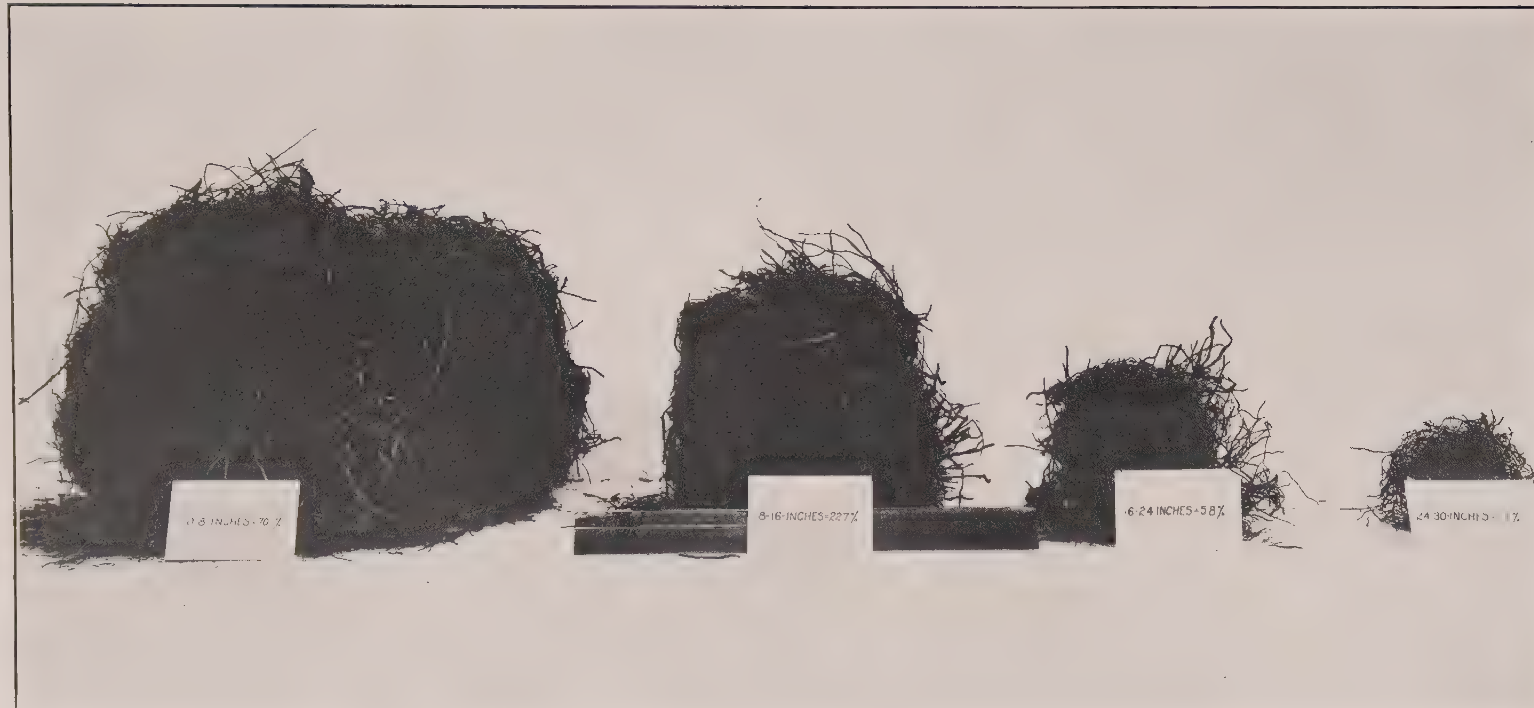
Depth in Soil	Average Weight of Roots per Stool in Grams	Percentage of Total Roots
Topmost 8 inches	72.5	70.0
8 to 16 inches	20.3	19.0
16 to 24 inches	8.7	8.0
24 to 32 inches	2.9	3.0
Totals	104.4	100.0

The soil was a loose loam, and the field yielded 35 tons of cane per acre.

Another determination, in Field H 41 of the Lihue Plantation Company, on cane of the same variety, age and treatment, which, however, yielded 75 tons of cane per acre, showed results as follows:

TABLE III

Depth in Soil	Average Weight of Roots per Stool in Grams	Percentage of Total Roots
Topmost 8 inches	107.3	73.0
8 to 16 inches	26.1	18.0
16 to 24 inches	11.6	7.0
24 to 32 inches	2.9	2.0
Totals	147.9	100.0



Note: This insert shows the labels denoting the strata from which the several masses of roots were taken. In the smaller illustrations the labels are not clear, but in each case from left to right are shown the roots from the upper stratum down, corresponding to the tables in the text.

The soil in this case also was a loose loam, and the cane had not been irrigated.

It should be noted that, although the quantity of roots was much greater in the field yielding 75 tons of cane per acre than in the field with 35 tons per acre, the percentages of roots in the different levels were practically identical in the two cases. The only difference in the cane lay in the yields, as the variety, age, soil texture and agricultural practice were the same in both fields.

A determination was made on plant Yellow Tip cane, unirrigated, seven months old, in Field 28 of the Kilauea Sugar Plantation Company. The following figures were obtained:

TABLE IV

Depth in Soil	Average Weight of Roots per Stool in Grams	Percentage of Total Roots
Topmost 8 inches	26.1	75.0
8 to 16 inches	5.8	17.0
16 to 32 inches	2.9	8.0
Totals	34.8	100.0

It is noticeable that although there was naturally a much smaller quantity of roots in the 7-months-old Yellow Tip than in the 26 months old cane, the proportion of the roots in the upper levels of the soil was only slightly greater in the younger cane. There are, of course, a number of variable factors other than the age of the cane to be considered in making a comparison with the roots from other plantations and fields.

The distribution of the roots of 11-months-old Badila cane was studied at the Kilauea Sugar Plantation Company. This was unirrigated plant cane in Field 29. The surface soil in this field was a thin loam, with the subsoil hard and compact. The results are shown below:

TABLE V

Depth in Soil	Average Weight of Roots per Stool in Grams	Percentage of Total Roots
Topmost 8 inches	31.9	68.75
8 to 16 inches	8.7	18.75
16 to 32 inches	5.8	12.50
Totals	46.4	100.00

The proportion of roots in the upper levels of the soil for this Badila cane was very nearly the same as for the H 109 of about the same age at Waipio.

A determination was made at Ewa Plantation with plant H 109 cane, 16 months old, in Field 3C. This field yielded 64.48 tons of cane per acre. The soil was a very sticky black adobe, which made the isolation of the roots difficult. Undoubtedly some of the smaller roots were lost, but the relative loss would be about the same for each level. The figures are as follows:

TABLE VI

Depth in Soil	Average Weight of Roots per Stool in Grams	Percentage of Total Roots
Topmost 8 inches	44.02	75.5
8 to 16 inches	11.06	18.9
16 to 24 inches	3.17	5.4
Totals	58.25	99.8

A second determination was made at Ewa, using second ratoon H 109 cane, 21 months old, in Field 13 E. The soil of this field, which yielded 113 tons of cane per acre, was a loose loam or alluvial silt, of very good physical quality to a depth of three or four feet. The results are shown below:

TABLE VII

Depth in Soil	Average Weight of Roots per Stool in Grams	Percentages of Total Roots	
Kuakua	3.57	2.20	Topmost
1 to 2 inches	28.94	17.86	8 inches
2 to 8 inches	68.09	42.03	62.09%
8 to 16 inches	38.04	23.48	
16 to 24 inches	14.38	8.87	
24 to 32 inches	7.18	4.43	
32 to 40 inches	1.76	.98	
Totals	161.96	99.85	

In this last determination, which is further illustrated in Figs. 4 and 5, there are some outstanding features. This cane had a greater proportion of its roots in the lower levels of the soil than any previously studied. Probably this fact is correlated with the excellent physical structure of the soil to a considerable depth. There may be some significance in the correlation of this deep rooting and the high yield of the field. Mr. Alexander, agriculturist at Ewa, stated that the cane in this field was difficult to ripen off; this possibly may be due to the large proportion of the roots being deep in the soil, where it would require several months for them to dry out.

This was the first determination of root distribution in ratoon cane, and it was expected that some difficulty might occur in separating the roots of the present crop from those of previous crops. However, no roots of previous crops were encountered, so it seems evident that in 21 months the old roots have completely rotted away.

At the Waipio substation a comparison was made of the roots of five plants of Lahaina cane, 3 months old, and five plants of H 109, grown under similar conditions, but planted ten days later. The results are tabulated below:

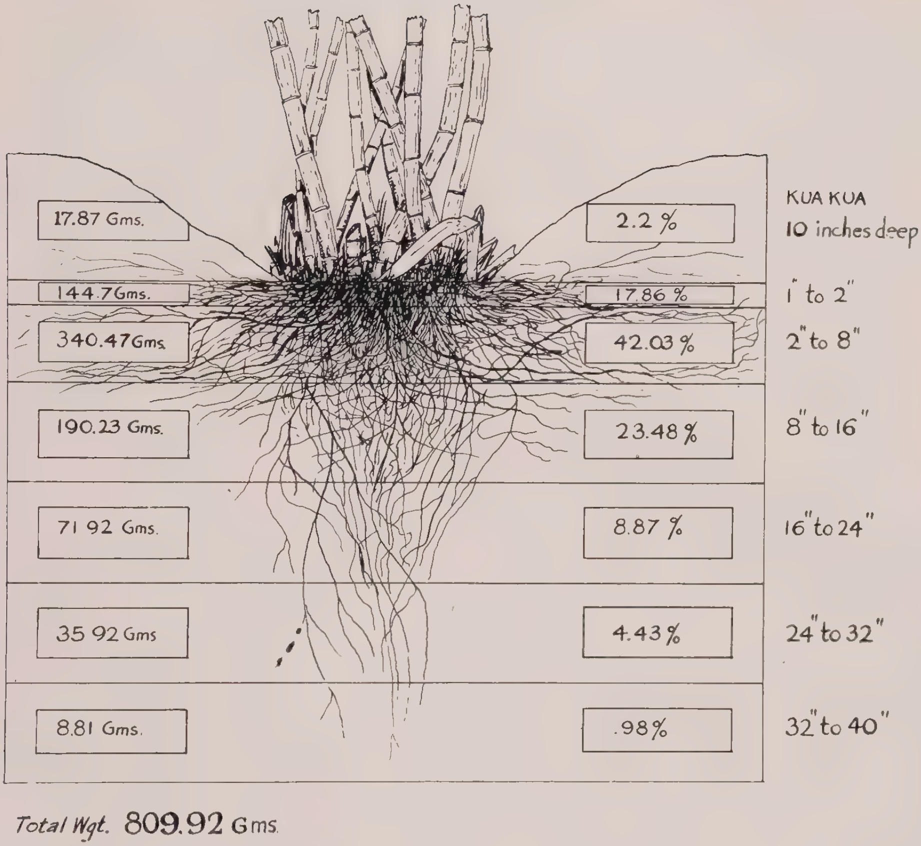


Fig. 4. Showing graphically the comparative masses of 21-month-old H 109 cane roots at different levels in the soil in Field 13-E at Ewa Plantation Company. The largest ratio of roots to the soil volume exists in the layer from 2 to 6 inches in depth, in this particular excavation. Drawing by J. A. H. Wilder.

TABLE VIII

Lahaina

Depth in Soil	Average Weight of Roots per Stool in Grams	Percentage of Total Roots
Topmost 8 inches	13.51	87.86
8 to 16 inches	1.74	11.32
16 to 24 inches	0.12	.80
Totals	15.37	99.98

H 109

Depth in Soil	Average Weight of Roots per Stool in Grams	Percentage of Total Roots
Topmost 8 inches	28.03	88.51
8 to 16 inches	3.21	10.13
16 to 24 inches	0.42	1.35
Totals	31.66	99.99

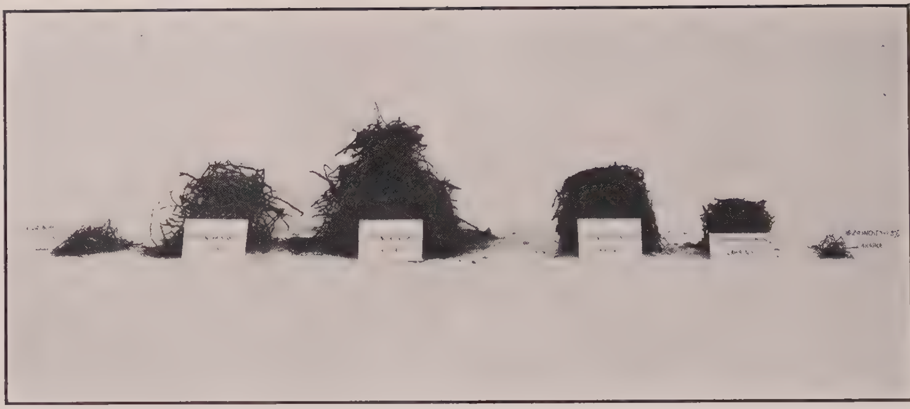


Fig. 5. Showing graphically the quantities of roots of 3-month-old Lahaina cane compared with the roots of H 109 of the same age under comparable conditions. There is only one-half the quantity of roots for the Lahaina cane as for the H 109, yet the proportions of roots in the different levels of the same are almost identical.

It is interesting that, in this comparison of the roots of 3-months-old Lahaina and H 109 at Waipio, the H 109 had more than 100 per cent more roots than the Lahaina, yet the percentages of roots in the different levels of soil were almost identical for the two varieties. This Lahaina cane was in an area which had previously suffered from one of the forms of Lahaina disease, and the roots were already abnormal, which would probably account for the unfavorable comparison of root weights with H 109.

Discussion

To the writer's knowledge such a method of determining quantitatively the distribution of the roots in the soil has not been developed previously for cane or for other crops.

A Large Proportion of the Roots is Above the 24-Inch Level in the Soil: The seemingly important result of these experiments, reporting as they do upon 45 plants, grown under very diverse conditions, is that in every case conservatively over 50 per cent of the roots were in the topmost eight inches of soil. It can be safely said, also, for these studies of cane in furrows, that more than 85 per cent of the roots are above the 24-inch level.

From the foregoing results, coupled with those obtained from the root-study boxes, which are not reported upon here, it seems evident that in young cane the proportion of roots in the upper levels of the soil is higher, but that as the cane grows older, the proportions of the root mass in the lower levels of the soil gradually increase. Even in the oldest cane studied to date, however, not more than 40 per cent of the roots were below eight inches in depth.

The distribution of the mass of cane roots in the soil under field conditions seems to be in the shape of a turnip, somewhat as shown in Fig. 5.

More Secondary Feeding Roots in the Upper Levels of Soil: The root masses in the upper layers of soil are usually lighter brown in color than the roots from the lower levels. The principal cause for this color difference results from the greater numbers of secondary roots in the upper layers of soil than in the lower levels; these secondary roots are light brown in color while the primary roots are usually black, so that the color difference usually seen between the different levels of soil has a significance, indicating that browner root masses have more secondary roots and usually greater areas of feeding surfaces.

More Cortex Rots of Roots in Deeper Levels of Soil: It was noted in all the determinations that roots in the deeper levels of the soil showed a much greater amount of rot in the outer layers, the cortex, than did the roots nearer the surface. Apparently, aeration in the upper levels of soil has a considerable influence in preventing cortex rots, and vice versa, the poorer aeration of the lower levels contributes to the occurrence of these rots.

Humus Returned to the Soil by Roots: The pushing of roots through the soil and their subsequent rotting away in subsequent crops, leaving channels, which we found commonly in the lower levels, must contribute somewhat to the better aeration of the soil. Organic matter also seems to have an influence in promoting aeration in the soil.

These experiments give a basis for calculating the amounts of humus returned to the soil by cane roots. Using 8,500 stools per acre as a basis for calculation, the H 109 cane with the greatest quantity of roots (Table I) would return about 1.85 tons of dry root material per acre, while the mature Yellow Tip with the smallest quantity (Table II) would return slightly less than one ton; these are figures for dry weights.

It seems evident that a workable method of studying the development and distribution of roots in the soil is available and comparisons of root systems under different soil environment and different methods of tillage, cultivation, irrigation and fertilization are now possible, which we propose to undertake.

Royden Bryan has assisted in the excavations of the roots in the field, and D. M. Weller and Z. A. Romero have made the weighings in the laboratory. Edward L. Caum has assisted greatly in the preparation of the manuscript.

The work recorded in the foregoing would have been impossible without the assistance of the plantations concerned, the Lihue Plantation Company, Ltd., the Kilauea Sugar Plantation Company, the Ewa Plantation Company, and the Waipio substation and appreciation is expressed to the personnel of these plantations for their ready and effective cooperation.

A Comparison of the Root Weights and Distribution of H 109 and D 1135 Cane Varieties

Excavations made at the Wailuku Sugar Company

By H. Atherton Lee

Using the methods outlined in a previous paper, root determinations for the variety D 1135 as compared with the variety H 109 were made in Fields 94 and 95 at the Wailuku Sugar Company.

Distribution of Roots of D 1135 in the Soil of Field 94

The part of the field in which the determinations were made is a very sandy loam to a depth of about 16 inches underlying which there is a stratum of pure sand for a depth of 5 to 6 inches and below that is a loose sandy loam.

The cane was 12 months old and had received 18 rounds of irrigation water, 200 pounds of nitrogen, 60 pounds of phosphoric acid and 60 pounds of potash per acre at the time of the excavation. The distribution of the roots by weight is shown in Table I, which follows:

TABLE I

Distribution of the Roots of D 1135 in Sandy Soil in Wailuku Field 94

Depth in Soil	Weight in Grams of Roots for 5 Plants	Average Weight in Grams per Plant	Per Cent
Kuakua*	94.14	18.83	10.25
0 to 8 inches	448.64	89.73	48.85
8 to 16 inches	170.12	34.02	18.52
16 to 24 inches	108.15	21.63	11.77
24 to 32 inches	65.70	13.14	7.15
32 to 40 inches	31.52	6.30	3.43
	918.27	183.65	99.97

The root masses of D 1135, obtained from the different levels in the soil in Field 94, are shown in the photograph in Fig. 1.

This is the first determination of the roots of D 1135 which has been made. It was surprising to observe the percentage of roots in the layer from 0 to 8 inches in depth for this variety. In previous determinations, mostly with H 109, the proportion of roots in the layer from 0 to 8 inches in depth has run from 60 to 75 per cent of the total roots. D 1135 in this one instance seems to be more deep rooted than H 109, but further comparisons need to be made to confirm this difference. Another noteworthy feature is the large quantity of roots for this variety; only the highest yielding fields in previous determinations have yielded from 800 to 900 grams of roots for 5 plants.

* The kuakua was from 10 to 13 inches in depth.

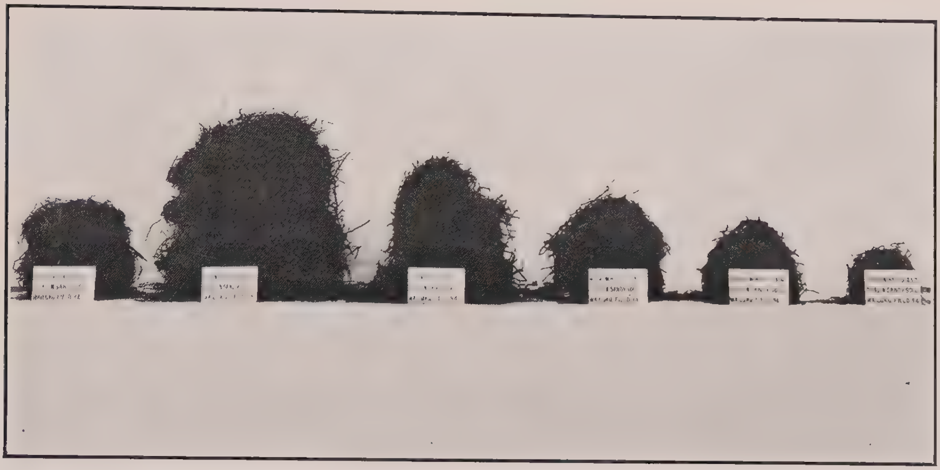


Fig. 1. Showing the root masses of D 1135 obtained from the different levels in depth in the soil in Field 94 at Wailuku.

Distribution of Roots of H 109 in Sandy Soil of Field 95

Across the road from Field 94, in Field 95 with a soil apparently identical to that of 94, 5 stools of H 109 plant cane, 11½ months old, were selected for root determinations. This H 109 cane had received 17 rounds of irrigation water, 200 pounds of nitrogen, 60 pounds of phosphoric acid and 60 pounds of potash per acre, at the time of the excavation. The distribution of roots of H 109 cane under these conditions, closely comparable to the conditions under which the D 1135 was growing, was then determined; the results follow in Table II.

TABLE II

Distribution of Roots of H 109 in Sandy Soil of Wailuku Field 95

Depth in Soil	Weight in Grams of Roots for 5 Plants	Average Weight in Grams per Plant	Per Cent
Kuakua*	22.19	4.44	3.65
0 to 8 inches	363.12	72.62	59.81
8 to 16 inches	147.72	29.54	24.33
16 to 24 inches	25.75	5.15	4.24
24 to 32 inches	27.22	5.44	4.48
32 to 40 inches	21.11	4.22	3.47
	607.11	121.41	99.98

The root masses of the above determination are shown in the photograph in Fig. 2.

The outstanding difference in the comparison between D 1135 and H 109 in these determinations, is the greater quantity of roots of the D 1135, amounting to about 50 per cent more than the H 109 by weight. D 1135 seems to be definitely more deeply rooted in this comparison than the H 109, there being 22.35 per cent

* The kuakua in this case was 6 to 8 inches in depth.

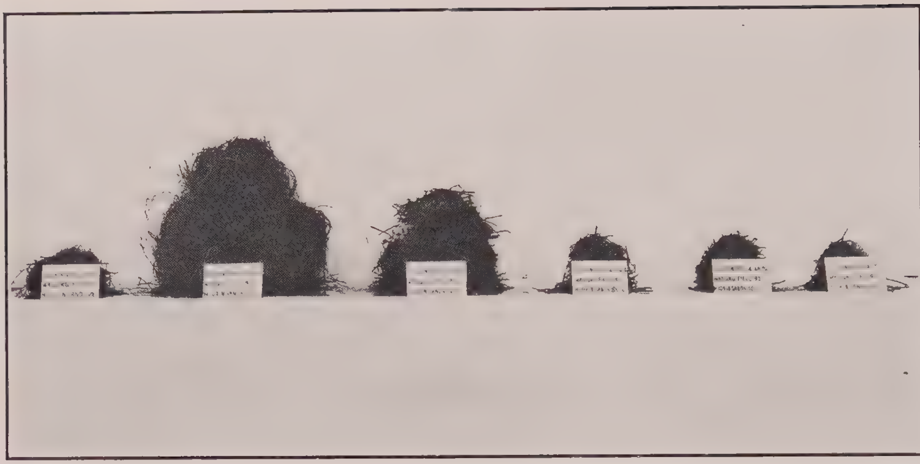


Fig. 2. Showing the root masses of H 109 obtained from the different levels in depth in the soil in Field 95 at Wailuku.

of the roots of D 1135 below the 16-inch level as compared to only 16.19 per cent below the same level for H 109. These results need to be corroborated by further comparisons of these varieties before such differences can be considered general.

In this case, the H 109 is more deep rooted than in any of the previous determinations for H 109. It is possible that the greater proportion of roots in the lower levels of soil in this case, is correlated with the sandy character of the soil which permitted aeration to greater depths in the soil than is the case with compact loamy soils.

Distribution of Roots of H 109 in Sandy Loam of Field 95

A second comparison was made between the H 109 in sandy soil, recorded in Table II, and H 109 in a more loamy soil higher up of the same field. The cane was approximately the same age and had received identical irrigation and fertilizer applications at the time of the excavations. The results follow in Table III:

TABLE III

Distribution of Roots of H 109 in Sandy Loam of Wailuku Field 95

Depth in Soil	Weight in Grams of Roots for 5 Plants	Average Weight in Grams per Plant	Per Cent
Kuakua	29.10	25.82	3.90
0 to 8 inches	409.36	61.87	54.96
8 to 16 inches	168.96	33.79	22.68
16 to 24 inches	69.31	13.86	9.30
24 to 32 inches	36.53	7.30	4.90
32 to 40 inches	31.55	6.31	4.23
	744.81	148.95	99.97

The results can be seen to be very similar for these two determinations, although there is a slightly greater quantity of roots in the loamy soil than in the sandy soil.

Weight of Roots is Correlated With Weight of Aerial Parts

It is interesting to make a comparison of the total root weights for these two determinations, with the weights of cane and cane tops from the same plants. The cane stalks and tops of the cane in sandy soil root determinations (shown in Table II) weighed 162 pounds as compared to a weight of 174 pounds for cane and tops of the H 109 in loamy soil. In this comparison there is a correlation between the quantities of roots and quantities of aerial parts. This correlation has been consistent in previous determinations so that it appears to be a definite conclusion that heavy root weights are correlated with heavy cane tonnage.

It is a pleasure to express appreciation to H. B. Penhallow and Neil Webster for their cooperation and interest in these studies.

A Comparison of the Root Distribution of Lahaina and H 109 Cane Varieties

Excavations made at the Hawaiian Commercial and Sugar Company

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By H. Atherton Lee

Using the methods outlined in a previous paper, root determinations for the variety H 109 as compared with the Lahaina variety were made in Fields 1 and 2 at the Hawaiian Commercial and Sugar Company. The results have an added interest in that they are the first ones obtained for hilled-up cane, all the previous determinations having been made for the roots of cane in furrows.

Distribution of the Roots of Lahaina Cane in the Soil of Field 2

The distribution of the roots was first determined for Lahaina ratoons, the previous crop of which had been harvested February 10 to 13, 1925; these ratoons were therefore 16 months old at the time of the determination. The present crop had received 181 pounds of nitrogen per acre and 63 pounds of phosphoric acid up to the time of these studies, according to Frank Broadbent. The soil in this field to a depth of 40 inches was a reddish loam which would appear fairly representative of the central Maui plain. This Lahaina cane was in fine condition with no indications of any growth failure. The distribution of the roots by weight is shown in Table I, which follows:

TABLE I

Distribution of Roots of 16-Months-Old Lahaina Ratoons in Field 2 at Puunene

Depth in Soil	Weight of Roots for 5 Plants in Grams	Average Weight per Plant in Grams	Per Cent
0 to 8 inches	354.26	70.85	19.09
8 to 16 inches	799.26	159.85	43.08
16 to 24 inches	434.84	86.97	23.42
24 to 32 inches	206.91	41.38	11.15
32 to 40 inches	60.26	12.05	3.24
Totals	1855.53	371.10	99.98

In the above determination the height of the hills, from the juncture of the cane with the soil, to the level of the furrows between the rows, was from 12 to 14 inches. This would limit the volume of soil in the topmost 8 inches, to a ridge less than 2½ feet broad at the 8-inch level and rising to an apex at the top of the hill. The ratio of roots to volume of soil would therefore be probably as high or higher in the uppermost 8 inches of soil, than in the level from 8 to 16 inches in depth.

Fig. 1. Showing graphically the root masses of 16-month-old Lahaina cane at different levels in depth in the soil.

The quantity of roots per stool of cane is very high in this determination, but because of the large excavation made (10 feet 10 inches long) the ratio of roots to the volume of soil is not unusual as compared to previous root determinations.

The root masses of the Lahaina cane in the different levels in depth in the soil are shown in Fig. 1.

Distribution of the Roots of H 109 in Field 1 at Puunene

Across the road from Field 2 where the root determinations were made on Lahaina cane, H 109 ratoons 15 months old, were growing in Field 1, in soil

similar in appearance to that in Field 2. The same fertilizer applications had been used and irrigation of both fields had been started within 20 days of each other. The H 109 was therefore under conditions fairly comparable to the conditions in which the Lahaina was growing, with the exception that the H 109 was one month younger than the Lahaina. The results from the determinations of roots for this H 109 cane follow in Table II.

TABLE II

Distribution of Roots of 15-Months-Old H 109 Ratoons in Field 1 at Puunene

Depth in Soil	Weight of Roots for 5 Plants in Grams	Average Weight per Plant in Grams	Per Cent
0 to 8 inches	240.71	48.14	12.86
8 to 16 inches	884.50	176.90	47.24
16 to 24 inches	474.91	94.98	25.26
24 to 32 inches	217.41	43.48	11.61
32 to 40 inches	54.81	10.96	2.92
Totals	1872.34	374.46	99.99

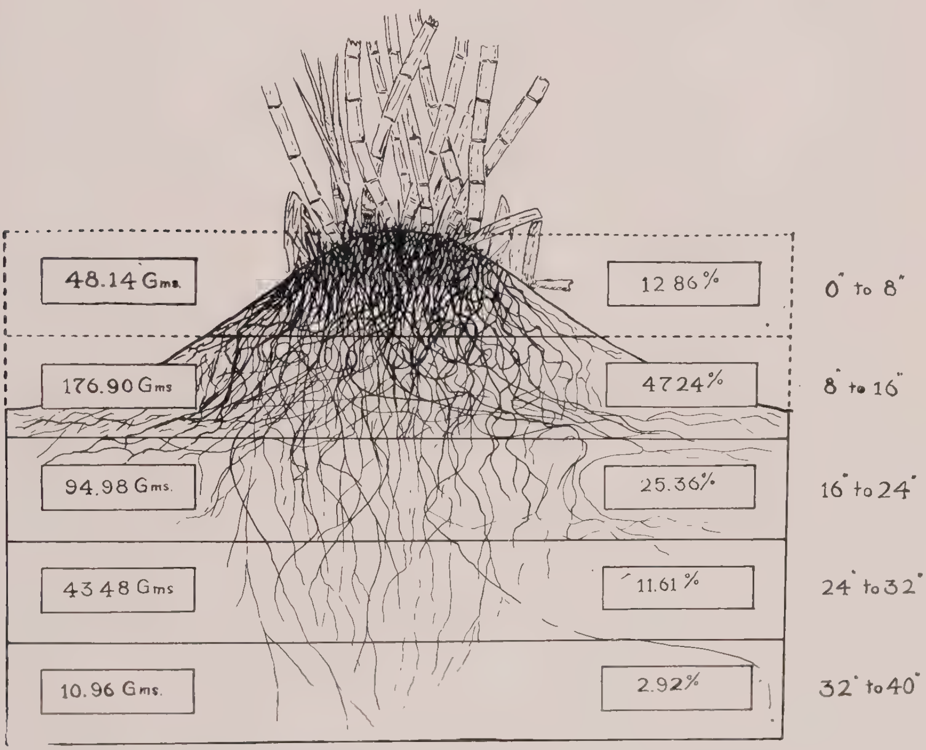

Fig. 2. A diagrammatic drawing by J. A. H. Wilder showing the distribution of the roots of H 109 under hilled-up conditions as found in Field 1.

The root masses of this H 109 in the different levels in depth in the soil are shown graphically in the photograph in Fig. 2.

The hills in the area from which these root excavations were made, were from 10 to 11 inches in depth from the juncture of the soil with the cane stalks, to the level of the furrows between the rows.

Comparison of Roots in Hilled-up Cane Versus Cane in Furrows

If one compares the root distribution of this hilled-up H 109 with previous results in which the H 109 has been in furrows, the outstanding difference is, that the largest percentage of roots is in the level from 8 to 16 inches in depth in the hilled-up cane, while in the cane in furrows the largest percentage of roots is in the topmost 8 inches.

Aeration of the soil has been stressed by many investigators as favoring root development and from the pathologist's viewpoint aeration might be expected to lessen fungus root rots. In hilled-up cane there would seem to be better aeration of the roots than in the case of the cane in furrows. This advantage, however, would possibly be more than balanced by the advantage to cane in furrows in that irrigation water, and nitrates in irrigation water, reach the greatest proportion of the roots of the cane when the cane is in the furrows than when the irrigation water runs between the rows in hilled-up cane.

Comparison of Root Distribution of Lahaina Versus H 109

There are no outstanding differences in this comparison of the roots of Lahaina and H 109. The H 109 is one month younger than the Lahaina, yet has a slightly heavier mass of roots. In the case of the Lahaina cane, 62.17 per cent of the roots are above the 16-inch level, while in the case of the H 109, 60.10 per cent are above the 16-inch level. This difference is so slight that one cannot say that one variety is markedly more deep rooted than the other.

Loss of Water and Nutrients from Cut Roots

Mr. Broadbent observed that the cut ends of roots from adjoining rows of cane, which extended into the area which had been excavated, would exude water or sap. This has been observed in other excavations since then, and there would appear to be a loss of water and nutrients from the plant from such cut roots sufficient to affect the plant unfavorably. This may be of interest in cultivation practices.

To Mr. Broadbent it is a pleasure to extend much of the credit for what appears in the foregoing studies.

The Determination of the Hydrogen Ion Concentration in the Cane Sugar Industry*

By Louis Baissac, F. C. S.,
Sugar Technologist, Department of Agriculture, Mauritius

Introduction

When a cane juice is limed neutral to litmus it is still acid to phenolphthalein; this fact has been known for many years by the practical sugar house man; more

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lime must be added to obtain neutrality to phenolphthalein. As a result, the terms neutral, acid or alkaline to litmus, or neutral, acid or alkaline to phenolphthalein are of current use in the sugar house.

The practical man knows well that there is a difference when he makes use of one or the other indicators and this difference is shown at the defecation stage by a more or less rapid settling. The object of defecation is to obtain a clear and brilliant juice from the turbid and foul one as extracted by mills.

The turbidity of the juice is caused by the presence of colloid substances (pectins, gums, albuminoids, coloring matter, etc.) which are always more or less acid, strictly speaking, and which are held in suspension in the juice in a special state, named pseudo-solution. According to the nature of the colloids, this state is modified by the application of heat, the addition of an acid, of an alkali or base, lime for example. Colloids are either coagulated and separated from the juice in the form of a flocculent or precipitate or are dissolved. It has been observed that a juice neutralized to litmus, whether previously treated with sulphurous acid or not, usually settles down more rapidly than if neutralized to phenolphthalein. It will be stated later on that, strictly speaking, a juice neutral to litmus is in fact an acid juice, while a juice neutral to phenolphthalein is in fact an alkaline juice.

What is meant by neutrality, acidity or alkalinity in absolute terms? It is first of all necessary to define the word Ion.* Electrolytic particles in solution which carry with them a quantity of electricity positive for hydrogen or metals, or negative for non-metals or radicles are called ions. These particles carrying electric charges are free in solution and have the property of moving in any possible direction, hence the word Ion.

For example, hydrogen is present in acids in the state of hydrogen ion. The property of acids of turning blue litmus red is due to the hydrogen ion. The difference between ions and elements in the free state is that the former are always present in pairs, they are always in solution and their properties are quite different from those of the free elements.

Hydrogen as an element is a gas without any action on litmus; the hydrogen ion can exist only in aqueous solution and it turns blue litmus red. Hydrogen ions are present in acid, neutral as well as alkaline aqueous solutions, but they are much more numerous in acid solutions. The same volume of a tenth normal solution of caustic soda must be added to neutralize an equal volume of a tenth normal solution of hydrochloric or acetic acid, and yet these two acids are of different strength. The tenth normal solution of hydrochloric acid contains 3.65 grams of HCl per litre whilst that of acetic acid contains 6.0 grams of $C_2H_4O_2$ per litre. Ten cubic centimetres of a tenth normal caustic soda solution which contains 4 grams of $NaOH$ per litre must be added to 10 c.c. of either of the tenth normal acid solutions for neutralization. How can it be accounted for, that the two acids are not of the same strength?

* The word Ion was given by Faraday, who borrowed it from the Greek; it means wanderer.

It has already been said that the property possessed by acids of turning blue litmus red is due to the hydrogen ion; the strength of the acid is due to the greater or smaller number of hydrogen ions present.

When an acid, a base or a salt is dissolved in water its molecules are divided into two parts carrying with them electric charges of opposite signs. For example: $HCl = H + Cl -$; $NaOH = Na + OH -$; $NaCl = Na + Cl -$. This phenomenon is called dissociation or ionization. All substances dissolved in water are not dissociated to the same degree. With the aid of special methods which will be mentioned later on it has been possible to determine that in a tenth normal solution of hydrochloric acid almost 95 per cent of the acid is dissociated in H ions and Cl ions, whereas in a tenth normal solution of acetic acid, only 1.3 per cent of the acid is dissociated in H ions and $C_2H_3O_2$ (acetic) ions. In the first case, there remains only 5 per cent of undissociated acid, whilst in the second 98.7 per cent of the acid remains undissociated.

When the caustic soda solution is added to the acid solution, the hydroxyl ion of the caustic soda combines with the hydrogen ion of the acid. When this combination is completed, another amount of the acid is dissociated, and a new addition of caustic soda solution again determines the combination. This goes on until all the acid is dissociated. If the reaction is made with litmus as indicator, the solution will remain red until the very moment when the last trace of acid will have been dissociated and will have combined with the caustic soda; then only the solution will turn blue, showing that there is no more dissociated hydrogen to combine with the hydroxyl of the caustic soda; the blue color is then due to the free hydroxyl left in the solution.

It is therefore obvious that by titration with caustic soda, the total amount of hydrogen ions contained in the acid is determined, and not the amount of free hydrogen ions existing at a given moment, i. e., the sum of actual and virtual ions or in other words, ionized hydrogen, and hydrogen that can be ionized or potential acidity. On the other hand, by the determination of hydrogen ions, the actual strength only of the acid is determined, this strength depending upon the degree of ionization.

It has long been wondered at why all acids do not invert cane sugar or sucrose to the same extent for a given concentration and temperature. The answer is in their degree of dissociation. The comparative inverting power of acids is to a certain point a measure of their dissociation or ionization.

As it may be seen, there is therefore an essential difference between total or potential acidity which may be determined with a standard alkali and active acidity caused by dissociation in positive hydrogen ions and in negative ions.

Meaning of the Term pH

Total acidity and active acidity are expressed in terms of normality. By titration with an alkali, the total amount of acid present is determined whilst in measuring the activity, only dissociated hydrogen ions are determined, and this quantity of dissociated hydrogen ions is expressed in terms of normality. Sorensen calls cH, the concentration of hydrogen ions per litre. If the amount present is

one gram per litre, cH will be equal to 1.0. If the concentration is 100 times less, that is to say, 1 gram per 100 litres, cH = 1/100, which may be written 10^{-2}; 1 gram in 10,000 litres will be cH = 1/10,000 or 10^{-4}, etc. As very small fractions or negative exponential values (such as —4, or —7, etc.) are inconvenient, Sorensen called pH, the numerical value of the negative exponent of 10.

$$cH = 10 - pH = \frac{1}{10\ pH} \text{ or } pH = \log 10 \frac{1}{cH},$$ which means that pH is equal

to the logarithm to the base 10 of the reciprocal of the hydrogen ion concentration expressed in grams per litre; or in other words, the common logarithm of the volume in litres containing 1 gram of hydrogen.

All substances in solution are more or less ionized. Even pure water follows this rule. The formula of water, H_2O, may be written HOH and HOH = H + OH. In that case, there is an equal amount of positive free hydrogen ions H and negative free hydroxyl ions OH. At normal temperature, there are 1/10th of a million gram molecule of hydrogen ions in 1 litre of water: 1/10000000 or more simply 1×10^{-7} gram molecule. Therefore water is 1×10^{-7} normal as regards hydrogen ions, and 1×10^{-7} normal as regards hydroxyl ions, the total ionization being 1×10^{-14}. When neutral salts are dissolved in water, this ratio is not altered, but when an acid is dissolved, there is H and negative free hydroxyl ions OH. Inversely, when a base is dissolved there is an excess of hydroxyl ions on hydrogen ions. However, whatever may be the quantity of H ions present, there is always a sufficient quantity of OH ions to maintain the above relation or ratio of 10^{-14} for the total quantity of ions. If the H ion concentration of a solution is 1×10^{-6}, normal or pH = 6, the hydroxyl ion concentration (OH) will be 1×10^{-8} normal or pH = 8.

Sorensen, the originator of this method, took it for granted that pH up to 6.99 indicates acidity; 7.0 will indicate absolute neutrality, i. e., the pH of pure water and figures above 7.0 will mean alkalinity. In other words, the lower the figure below 7.0, the higher the active acidity of the solution and the higher the figure above 7.0, the higher its active alkalinity.

For example, let us consider a cane juice as extracted by mills, this juice after sulphitation, then limed to normal defecation point and slightly alkaline to litmus; lastly filter press juice from muds difficult to filter and limed to slight alkalinity to phenolphthalein (which is met with unfortunately too often in practice). Let us suppose 5.6 to be the pH of the mill juice; 3.6 that of the sulphured juice which becomes 6.8 after liming and the filter press juice to be pH 8.8. The sulphur juice will be more actively acid than the mill juice; the limed juice will be almost neutral and the filter press juice will be very alkaline. These figures have at the same time intrinsic values; the sulphured juice will be 100 times as actively acid as the mill juice, and the latter will be about 16 times as actively acid as the limed juice; this limed juice will be only 1.6 times as actively acid as water which means almost practical neutrality. The filter press juice will be alkaline: 63 times more alkaline than pure water. These numerical values are explained as follows: the difference between log 5.6 and log 3.6 is log 2.0. The natural number whose logarithm is 2 is 100. In the same way, the difference between 6.8 and 5.6 is 1.2;

15.8 is the natural number whose logarithm is 1.2. Between 7.0 and 6.8 there is but a difference of .2 and the natural number corresponding to log .2 is 1.58. Lastly the difference between 8.8 and 7.0 is 1.8, the log of 63.1.

It is essential to note that a difference of 2.0 in the pH of two solutions means that there is in one of them 100 times more or 100 times less ions than in the other, whilst a difference of 1.0 means that the hydrogen ion concentration is only 10 times more or 10 times less and if the difference is only .1 the hydrogen ion concentration differs but by 1.26 times.

Methods for the Determination of pH

There are several methods for the determination of the hydrogen ion concentration or pH, but the two more commonly employed are the electro or potentiometric, and the colorimetric. For current laboratory or industrial needs, the colorimetric method is quite sufficient although not so accurate; it is much simpler and can be made use of by anybody in the sugar house; it is almost as simple as the use of litmus paper. The potentiometric method will not be described in this bulletin.

The colorimetric method is based upon the change of color or shade which takes place when solutions of different indicators are submitted to gradual changes in pH. Most indicators show a maximum change for a small range in the pH.

Indicators (such as litmus, methyl orange, phenolphthalein, etc.) are weak organic acids (or bases) liable to form salts. In solution these indicators are dissociated exactly as mineral acids or salts and their anions (or negative ions) differ in color from the dissociated acids. In an alkaline medium, the indicator forms a salt totally dissociated. In an acid medium, the free acid only is present and is but very slightly dissociated, this dissociation being reduced to a minimum if there is an excess of H ions present. At intermediate stages between these two extremes, there are mixtures of salts and undissociated acid and consequently mixtures of colors. For example, let us consider the case of litmus, to which everyone in the sugar house is familiar; undissociated azolitmin, (the acid of its coloring matter) is red in acid solution whilst the neutralized and totally dissociated salt is blue. Between these extremes, there are mixtures of red and blue—all the purple shades—everyone corresponding to a certain pH. When half the coloring radical is dissociated, the colors are in equal proportions, and the slightest change in the pH will show a rapid change in the resulting shade. All the indicators behave similarly. This is the basis of the method of the determination of pH. (When the indicator is a weak basis the phenomena are the same, but reversed.)

The following is a list of a few indicators with their extremes: the first figure is the pH at which dissociation starts and the second that of total dissociation. A pH lower than the first figure does not modify the initial color, and in the same way a pH higher than the second one.

Name of the Indicator	Concentration Grs. Per Cent c.c.	Change of Color	Limits of pH
Bromophenol blue	0.04	from yellow to blue........	3.0— 4.6
Methyl orange	0.02	" red to yellow........	3.1— 4.4
Methyl red	0.02	" red to yellow........	4.4— 6.0
Bromocresol purple	0.04	" yellow to purple......	5.2— 6.8
Bromothymol blue..........	0.04	" yellow to blue.......	6.0— 7.6
Litmus (azolitmin)	....	" red to blue..........	4.5— 8.3
Phenol red	0.02	" yellow to red........	6.8— 8.4
Cresol red	0.02	" yellow to red........	7.2— 8.8
Phenolphthalein	0.05	" colorless red	8.3—10.0

It will be noticed that the indicator the more commonly employed in the sugar factories in Mauritius, litmus, is the one with the wider range, which makes it the less sensitive.

The *modus operandi* for the determination of the pH of a solution by the colorimetric method is as follows: —10 c.c. of the solution are measured in a 16 m/m diameter test tube* to which are added from 0.3 to 0.5 c.c. of the suitable indicator; the same volume of the solution is measured in another test tube; but in this one no indicator is added; the two tubes are placed in a "comparator," one near the other. A test tube filled with pure water is placed in front of the tube containing the solution with the indicator and in front of the other is placed the tube filled with a "buffer" solution of a known pH, colored with the same indicator; when the shade of the solution is the same as that of the buffer, the solution is of the same pH as the buffer.

The most convenient buffer is the one prepared by the "British Drug Houses, Ltd.," of London, and known as the B. D. H. Universal buffer solution. It is composed of a salt (Dr. E. B. R. Prideaux's formula) of which a certain weight is dissolved in one litre of pure neutral water.† The pH of the solution is constant; by the addition of known volume of 1/5 normal solutions of hydrochloric acid or caustic soda, the pH of the original B. D. H., buffer solution is modified to the required pH. A set of buffer solutions with a constant difference of 0.2 pH is prepared, the suitable indicator is added accordingly and the standards so obtained will keep pretty well in sealed tubes.

A convenient comparator is the one described by Mansfield Clark (The determination of hydrogen ions, p. 70, 1922). It may be made from a block of wood. Six deep holes just large enough to hold ordinary test tubes are bored parallel to one another in pairs. Adjacent pairs are placed as close to one another as can be done without breaking through the intervening walls. Perpendicular to these holes and running through each pair are bored smaller holes through which the test tubes may be viewed. Before use, it is well to paint the whole block and especially the holes, a non-reflecting black.

* Test tubes must be of first quality, neutral, colorless glass; ordinary glass gives up alkalinity even to pure water and is objectionable.

† Distilled water is usually acid, and the pH of natural waters—spring, river or well—is very variable. Mare-aux-Vacoas water, for instance, is alkaline; pH 8.5—8.6. It is very easy to neutralize any water to pH 7.0.

Application of the Colorimetric Method

The colorimetric method for the determination of pH in the cane sugar manufacture was first applied by H. F. Brewster and W. G. Raines, Jr., in Louisiana, and the results obtained were presented by the authors at the meeting of "The American Chemical Society" held in Birmingham, Ala., U. S. A., in April, 1922—Division of Sugar Chemistry.

The authors, instead of using test tubes and comparator, employed the drop plate method; they added one drop of the appropriate indicator solution to three drops of the test liquid contained in the depression of a porcelain spot plate. The color thus obtained was matched with similar spots made by adding one drop of the same indicator to three drops of a standard buffer.

The comparison with buffers is valuable especially when the solution to be tested has a pH which does not permit of the use of bromothymol blue.

For quick and approximate determinations (+ 0.1 pH), the comparison with Clark's color chart is good enough. Mr. R. G. W. Farnell, research chemist of the British Empire Sugar Research Association, applies it as follows:

To 2 c.c. of juice or 1 c.c. of syrup (Clairce) measured in a test tube and diluted to 10 c.c. with neutral water (pH 7.0), (.@), 0.3 to 0.5 c.c. of the required indicator are added; the tube is placed in the comparator and the color is compared with that of the chart for the indicator employed.

Dilution does not modify much the pH, particularly for neutralized juices and raw syrups (Clairces), in which cases the determination of the pH with bromothymol blue and the match with the color chart is accurate enough.

When dealing with mill and sulphured juices, acidified syrups (Clairces) and limed filter press juices, the pH is not much modified by dilution, but matching is sometimes difficult because the colors do not agree exactly; the operator must use some imagination and discretion to judge of the difference of colors and find the agreement between the shades.

Practical Considerations and Results Obtained

It has already been seen that a juice neutralized to litmus settled more quickly than when neutralized to phenolphthalein. This is due to the fact that in the first case, the pH of the juice is nearer to the optimum at which colloids settle readily. When lime is gradually added to a sulphured juice, pH (3 to 4), it combines with the sulphurous acid to form calcium sulphite and with the acids pre-existing in the juice; as the pH increases, that is to say, as the acidity is lessened, the colloids coagulate until a point is reached when they rapidly settle, leaving a clear, supernatent liquid. According to research made in other cane countries, and observations made this year in Mauritius by Farnell and the writer, this optimum pH is very near 7.0. If the amount of lime is increased, the colloids expand, are more hydrated and bulky, the more so as the pH will be higher. As phenolphthalein begins to show a pink shade at pH 8.5, if this indicator is made use of, it is obvious that the settling will be slower and the colloidal deposit more bulky than in the case of litmus.

In Mauritius the juice is first sulphured, then limed. The man in charge of the liming, locally called "sucrier," adds lime to the juice up to a slight alkalinity to

litmus. He takes in a glass or test tube a sample of the juice so treated, and observes the flocculent precipitate formed. According as the precipitate settles more or less rapidly, as it is more or less bulky and as the supernatent liquid is more or less clear, he is satisfied with the liming point. If not, he adds some more lime in the tank if he considers it necessary; on the other hand, if he thinks too much lime has been added, he will put less in the following tank. This man in charge is unaware that he has found out the optimum pH of that particular juice. This figure seems very constant for a factory dealing with the canes of the same locality. If the man in charge is clever he will stick to the optimum pH and the resultant clear juice will be satisfactory. He will use litmus paper only occasionally.

There are cases when this *modus operandi* is defective—with very dark colored cane, for instance. The man in charge is puzzled and is inclined to use too little lime because of the dark color of the supernatent juice. In such cases, the determination of the pH with bromothymol blue may help. At all events, the determination of the pH permits of obtaining a more regularly clear juice and does away with the cleverness of the "sucrier."

In 1923, the writer was asked to follow the application of the Bach process at Highlands; he noticed that the filtration of the treated syrup was irregular and sometimes very difficult. Regular good filtration was obtained when he applied the method of the determination of the hydrogen ion concentration—pH 6.8 to 6.9—litmus was not reliable; judging by the settling of the precipitate was impossible—for the precipitate was composed almost exclusively of calcium sulphite and a very small percentage of colloids. If sulphitation was stopped when litmus showed a light blue shade, inversion occurred, and when phenolphthalein was employed as indicator, filtration was almost impossible. The determination of the optimum pH solved the difficulty.

Conclusion

Amongst many others there are two important points to be watched during the manufacture of sugar: excess of active acidity, causing the inversion of sucrose, and excess of active alkalinity which decomposes reducing sugars.

Inversion is a cause of loss dreaded by the practical man; destruction of reducing sugars is also a cause of loss which should be dreaded, for any destruction of these sugars means the retention of about an equal amount of sucrose by salts in final molasses, according to Prinsen Geerligs' unquestionable theory.

There is a rather narrow range of pH between the beginning of inversion and the destruction of reducing sugars; the more so when the sugar solution is of a low specific gravity and at a high temperature; the determination of the hydrogen ion concentration at the successive stages of the manufacture of sugar enables of their prevention.

(W. R. M.)

Sugar Prices

96° Centrifugals for the Period June 16, 1926, to September 15, 1926

Date	Per Pound	Per Ton	Remarks
June 16, 1926	4.18¢	$83.60	Cubas.
" 17	4.16	83.20	Cubas, 4.14, 4.18.
" 18	4.14	82.80	Cubas.
" 22	4.11	82.20	Porto Ricos.
" 25	4.08	81.60	Cubas.
" 29	4.16	83.20	Cubas, 4.14; Porto Ricos, 4.18.
" 30	4.18	83.60	Porto Ricos.
July 7	4.195	83.90	Cubas, 4.21; Philippines, 4.18.
" 8	4.16	83.20	Cubas, 4.14, 4.18.
" 9	4.14	82.80	Cubas.
" 14	4.11	82.20	Cubas.
" 15	4.095	81.90	Cubas, 4.11, 4.08.
" 16	4.11	82.20	Cubas.
" 19	4.14	82.80	Cubas.
" 21	4.125	82.50	Cubas, 4.14, 4.11.
" 22	4.125	82.50	Philippines, 4.14; Cubas, 4.11.
" 23	4.14	82.80	Philippines.
" 26	4.18	83.60	Cubas.
" 27	4.195	83.90	Porto Ricos, 4.18; Cubas, 4.21.
" 28	4.18	83.60	Cubas.
Aug. 3	4.21	84.20	Cubas.
" 4	4.225	84.50	Cubas, 4.21; Philippines, 4.24.
" 5	4.21	84.20	Cubas.
" 9	4.27	85.40	Cubas.
" 11	4.225	84.50	Cubas, 4.24, 4.21.
" 16	4.24	84.80	Cubas.
" 24	4.22	84.40	Cubas.
" 25	4.21	84.20	Cubas.
" 27	4.27	85.40	Cubas.
Sept. 8	4.33	86.60	Cubas.
" 10	4.38	87.60	Cubas, 4.36, 4.40.
" 13	4.43	88.60	Porto Ricos.
" 15	4.40	88.00	Philippines.

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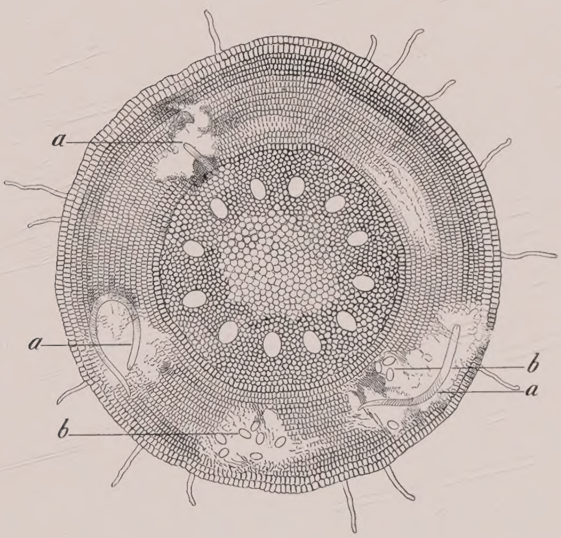
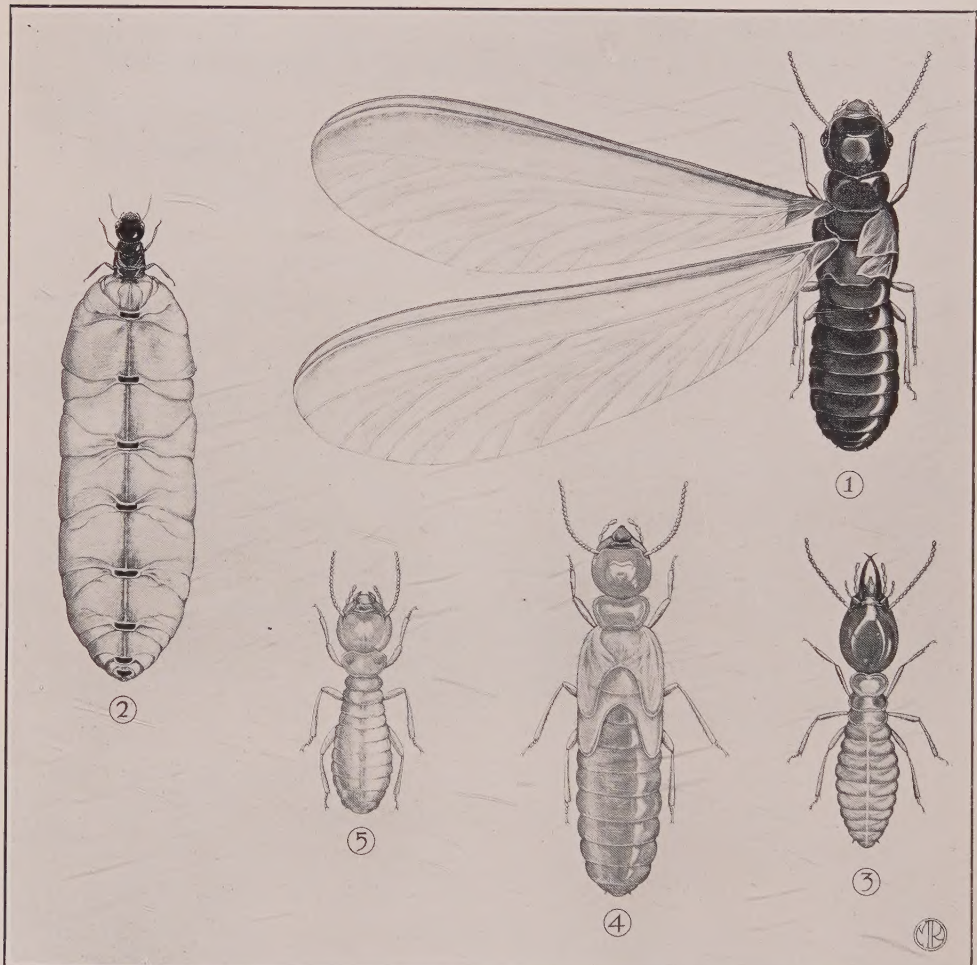
ILLUSTRATIONS APPEARING ON THE COVERS OF VOLUME XXX

APRIL

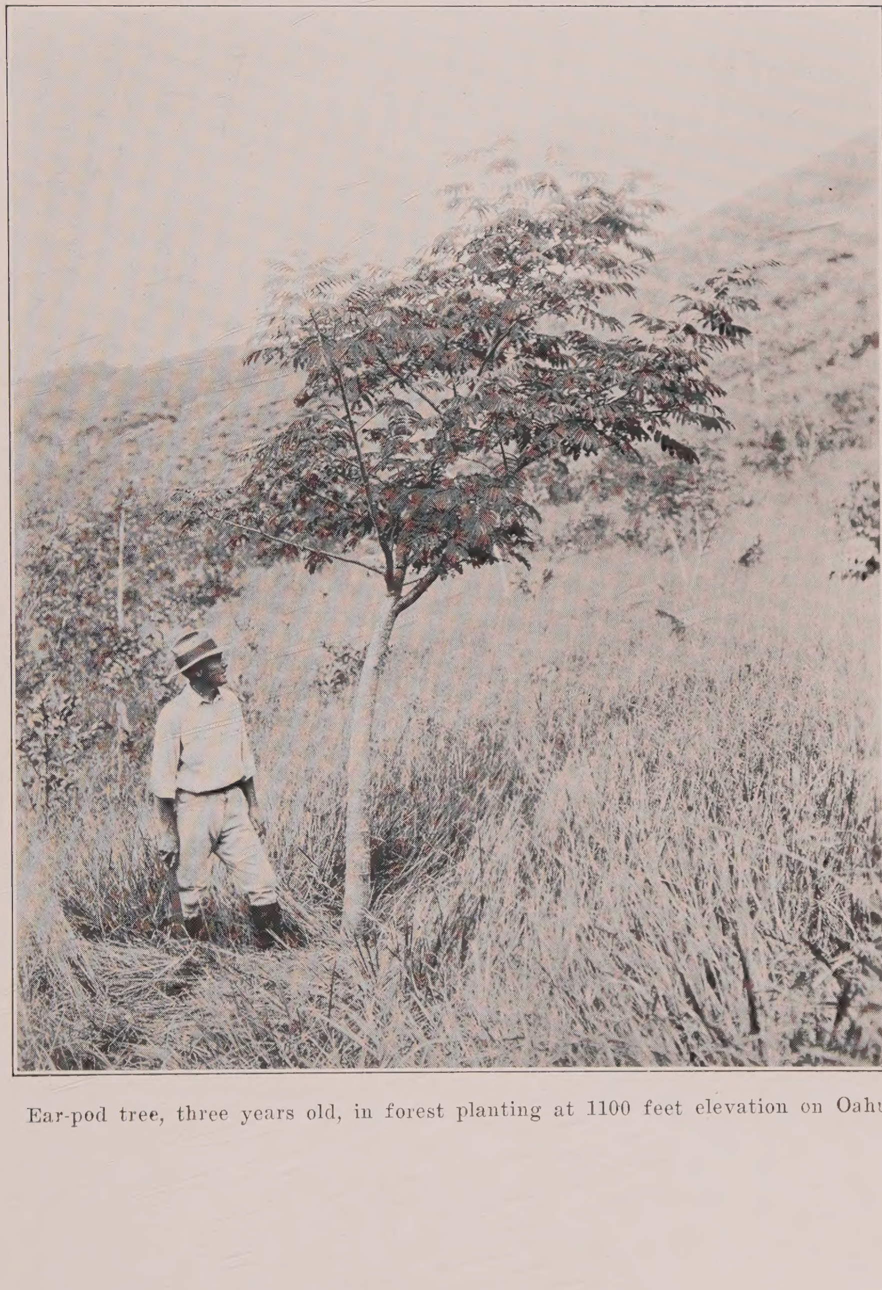


Cross section of cane root of D 1135 injured by the nematode *Tylenchus similis.* *a*, nematode; *b*, eggs. X ± 30.



Coptotermes intrudens, one of the termites which is causing damage to buildings in Honolulu and elsewhere.

OCTOBER



Ear-pod tree, three years old, in forest planting at 1100 feet elevation on Oahu.